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JAMES COPE CADMAN,

PRESIDENT OF THE INSTITUTION OF MINING ENGINEERS, 1903-1904.

TRANSACTIONS

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HAGGIE, D. H. AND G., Wearmouth Patent Rope Works, Sunderland. N. E.
HARTLEY, CYRIL J., Drysdale House, Stone, Staffordshire. N. S.
HARTON COAL COMPANY, LIMITED, The Harton Collieries, South Shields. N. E.
HETTON COAL COMPANY, Fence Houses. N. E.

JOICEY, JAMES, AND COMPANY, LIMITED, Newcastle-upon-Tyne. N. E.
JONES, HERBERT ALEXANDER, Myrtle House, Harrogate Road, Undercliffe, Bradford. M. I.

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LOBL. GROSSECHE BUCHHANDLUNG, Clausthal, Harz, Germany.
LOBL. VOSS SORTMENT BUCHHANDLUNG, Leipzig, Germany.
LONDONDERRY, THE MOST HONOURABLE THE MARQUESS OF, c/o Vincent Charles Stuart Wortley Corbett, Londonderry Offices, Seaham Harbour, Sunderland. N. E.

MACKENZIE, GEORGE L., c/o W. D. Mackenzie, Terraughtie, Dumfries. S. S.
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PARRY, DAVID EBENEZER, Norton Cannock Colliery, Bloxwich, Walsall. S. S.
PERRY, PERCIVAL JOHN, Villiers Road, Abergwynfi, Blaengwynfi, Port Talbot. S. S.

RENSHAW, WILLIAM ROBERT, Phœnix Foundry and Boiler Works, Stoke-upon-Trent. N. S.
RYHOPE COAL COMPANY, Ryhope Colliery, Sunderland. N. E.

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SMITH, M. FRITZ, Church Hill, Hednesford, S.O., Staffordshire. S. S.
SOCIÉTÉ HOULLIÈRE DE LIÉVIN (PAS-DE-CALAIS), Liévin, Pas-de-Calais, France. N. E.
SOUTH HETTON AND MURTON COLLIERIES, OWNERS OF, 50, John Street, Sunderland. N. E.
STECHERT, G. E., AND COMPANY, 2, Star Yard, Carey Street, London, W.C.
STELLA COLLIERY, OWNERS OF, Hedgefield, Blaydon-upon-Tyne, S.O., County Durham. N. E.
STRATHERN, ALEXANDER G., 41, Blairhill Street, Coatbridge. S. I.

THROCKLEY COLLIERY, OWNERS OF, Newcastle-upon-Tyne. N. E.
TOMITA, TARO, c/o Mitsui Mining Company, Miike, Japan. M. I.

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WARDLE, G. R., Conduit Colliery, Norton Canes, Cannock, S.O., Staffordshire. S. S.
WEARMOUTH COLLIERY, OWNERS OF, Sunderland. N. E.
WESTPORT COAL COMPANY, LIMITED, Dunedin, New Zealand. N. E.
WICKETT, F., Penarth, Redruth, Cornwall. S. S.
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AGASSIZ, ALEXANDER, Cambridge, Massachusetts, U.S.A. M. G.

BARNES, J., South Cliff House, 301, Great Clowes Street, Higher Broughton, Manchester. M. G.
BAXTER, ANDREW, Whifflet Station, Coatbridge. S. I.
BELL, THOMAS, 16, Grosvenor Road, Scarborough. M. G.
BLACK, W. G., 2, George's Square, Edinburgh. M. G.
BOLTON, HERBERT, The Museum, Bristol. M. G.

BRANCKER, RICHARD, The Pearson and Knowles Coal and Iron Company, Limited, 11, Old Hall Street, Liverpool. M.G.
BROECK, ERNEST VAN DEN, 32, Place de l'Industrie, Bruxelles, Belgium. M.G.
BROWN, MARTIN WALTON, 10, Lambton Road, Newcastle-upon-Tyne. S. I.

CAMERON, WILLIAM, Finnie Street, Kilmarnock. S. I.
CAMPBELL, HENRY HUNTER, 444, Produce Exchange, Manchester. M.G.
COLE, ROBERT HEATH, Endon, Stoke-upon-Trent. M.G.
COLLIER, REV. E. C., St. Peter's Vicarage, Birkdale, Southport. M.G.
CRAWFORD AND BALCARRES, THE RIGHT HONOURABLE THE EARL OF, Haigh Hall, Wigan. M.G.

DICKINSON, JOSEPH, 3, South Bank, Sandy Lane, Pendleton, Manchester. M.G.

EDMONDSON, J. H., Garswood Hall Collieries, Wigan. M.G.

FERGUSON, DAVID, 140, Hyndland Drive, Kelvinside, Glasgow. S. I.

GEIKIE, SIR ARCHIBALD, Director-General of the Geological Survey of the United Kingdom, 28, Jermyn Street, London, S.W. M.G.
GILLOTT, J. W., Lancaster Works, Barnsley. M.G.
GREGSON, GEORGE ERNEST, 11, Chapel Street, Preston. M G.

HALL, HENRY, H.M. Inspector of Mines, Rainhill, S.O., Lancashire. M.G.
HALL, LEVI J., Morland House, Birch Vale, Stockport. M G.
HARROWER, D. K., Knowe Park, Bo'ness, S.O., Linlithgowshire. S. I.
HEATHER, FRANK, 47, Mosley Street, Manchester. M.G.
HENSHAW, ALBERT MAYON, Talk-o'-th'-Hill Colliery, Talke, Stoke-upon-Trent. M.G.
HIGSON, JOHN, Crown Buildings, 18, Booth Street, Manchester. M.G.
HINNELL, H. LEONARD, 41, Corporation Street, Manchester. M.G.
HOWSIN, EVELIN G., Simonstown, Burnley. M.G.
HULL, EDWARD, 14, Stanley Gardens, Notting Hill, London, W. M.G.
HYSLOP, WILLIAM, Bank Colliery, New Cumnock, S.O., Ayrshire. S. I.

JOBLING, ALBERT, 91, Rectory Road, Burnley. M.G.
JOBLING, HENRY, 91, Rectory Road, Burnley. M.G.

KINAHAN, G. H., Woodlands, Fairview, Dublin. M.G.
KRAUSS, JOHN SAMUEL, Stonycroft, Knutsford Road, Wilmslow, Manchester. M.G.

LANDLESS, RICHARD, Bank Hall Colliery, Burnley. M.G.
LATHAM, DANIEL, Rosebridge and Ince Hall Collieries, Wigan. M.G.
LEECH, ARTHUR HENRY, 11, King Street, Wigan. M.G.
LOGAN, WILLIAM, 6, Merchiston Place, Edinburgh. S. I.
LORD, JAMES, Hill House, Rochdale. M.G.

MACALPINE, GEORGE WATSON, Altham and Great Harwood Collieries, Accrington. M.G.
McDONALD, JOHN, Glencoe, Cleland, S.O., Lanarkshire. S. I.
McGILL, JAMES, Craigowan, Hollandbush, Glasgow. S. I.
MARTIN, JOSEPH SAMUEL, I.S.O., H.M. Inspector of Mines, The Vikings, 16, Durdham Park, Bristol. M.G.
MORROW, SAMUEL, Palacecraig, Airdrie. S. I.

NOAR, T. LAMB, c/o T. Noar, Cairnsmoor, North Drive, St. Anne's-on-the-Sea, Lancashire. M.G.

PICKUP, P. W. D., Rishton Colliery, Rishton, Blackburn. M.G.

REID, ALEXANDER, Willow Lodge, Hoole Road, Chester. *Transactions* to be sent to c/o Walter A. Reid, 6, Golden Square, Aberdeen. M.G.
ROBERTSON, DAVID, 135, Waterloo Street, Glasgow. S. I.

ROBERTSON, JOHN, Jun., 24, St. Vincent Place, Glasgow. S. I.
RUSSELL, JOSEPH, Newton Colliery, Newton, Glasgow. S. I.
RUSSELL, ROBERT, Coltness Iron Works, Newmains, S.O., Lanarkshire. S. I.

SELBY, JOHN BASELEY, Leigh. M. G.
SETTLE, JOEL, The Hill, Alsager, Cheshire. M. G.
SHUTTLEWORTH, THE RIGHT HONOURABLE LORD, Gawthorpe, Burnley. M. G.
SIMPSON, W. W., Winkley, near Whalley, Blackburn. M. G.
SMETHURST, WILLIAM, Brynmair, Dolgelly. M. G.
SMITH, RICHARD CLIFFORD, Ashford Hall, Bakewell. M. G.
SQUIRE, JOHN BARRET, 7, Clifton Hill, St. John's Wood, London, N.W. M. G.
STIRRUP, MARK, High Thorn, Stamford Road, Bowdon, Altrincham. M. G.
SUTCLIFFE, RICHARD, Horbury, Wakefield. M. G.

TAYLOR, WILLIAM, 51, Park Road, Darwen. M. G.
TIMMINS, ARTHUR, Argyll Lodge, Higher Runcorn. M. G.
TRAFFORD, SIR HUMPHREY FRANCIS DE, Bart., 13, Charles Street, Berkeley Square, London, W. M. G.

WALKDEN, RICHARD, 26, Watery Lane Terrace, Spring Vale, Darwen. M. G.
WALKER, THOMAS A., Pagefield Iron Works, Wigan. M. G.
WALMESLEY, OSWALD, 2, Stone Buildings, Lincoln's Inn, London, W.C. M. G.
WARD, ALEXANDER HOUSTONNE, Raneegunge, Bengal, India. M. G.
WEIR, THOMAS D., c/o Brown, Mair, Gemmell and Hislop, 162, St. Vincent Street, Glasgow. S. I.
WELLS, LIONEL B., 75, Haworth's Buildings, 5, Cross Street, Manchester. M. G.
WHITAKER, WILLIAM, Freda, Campden Road, Croydon. M. G.
WILLIAMS, SIR EDWARD LEADER, Ship Canal Company, Spring Gardens, Manchester. M. G.

YOUNG, WILLIAM, 109, St. Vincent Street, Glasgow. S. I.

THE INSTITUTION OF MINING ENGINEERS.

SUBJECTS FOR PAPERS.

The Council of The Institution of Mining Engineers invite original communications on the subjects in the following list, together with other questions of interest to mining and metallurgical engineers.

Assaying.
Boiler explosions.
Bore-holes and prospecting.
Boring against water and gases.
Brickmaking by machinery.
Brine-pumping.
Canals, inland navigation, and the canalization of rivers.
Coal-getting by machinery.
Coal-washing machinery.
Coke manufacture and recovery of bye-products.
Colliery leases, and limited liability companies.
Compound winding-engines.
Compressed-air as a motive-power.
Corrosive action of mine-water on pumps, etc.
Descriptions of coal-fields.
Diamond-mining.
Distillation of oil-shales.
Drift and placer-mining.
Duration of coal-fields of the world.
Electric mining lamps.
Electricity and its applications in mines.
Electro-metallurgy of copper, etc.
Engine-counters and speed-recorders.
Explosions in mines.
Explosives used in mines.
Faults and veins.
Fuels and fluxes.
Gas-producers and gaseous fuel and illuminants.
Gas, oil and petroleum engines.
Geology and mineralogy.
Gold-recovery plant and processes.
Graphite: its mining and treatment.
Haulage in mines.
Industrial assurance.
Inspection of mines.
Laws of mining and other concessions.
Lead-smelting.
Light railways.
Lubricating value of grease and oils.
Lubrication of trams and tubs.
Maintenance of canals in mining districts.
Manufacture of fuel-briquettes.
Mechanical preparation of ores and minerals.
Mechanical ventilation of mines, and efficiency of the various classes of ventilators.
Metallurgy of gold, silver, iron, copper, lead, etc.
Mining and uses of arsenic, asbestos, bauxite, mercury, etc.
Natural gas, conveyance and uses.
Occurrence of mineral ores, etc.
Ore-sampling machines.
Petroleum-deposits.
Preservation of timber.
Prevention of over-winding.
Pumping machinery.
Pyrometers and their application.
Quarries and methods of quarrying.
Rock-drills.
Safety-lamps.
Salt-mining, etc.
Screening, sorting and cleaning of coal.
Shipping and discharge of coal-cargoes.
Sinking, coffering and tubbing of shafts.
Sleepers of cast-iron, steel and wood.
Spontaneous ignition of coal and coal-seams.
Stamp-milling.
Steam-condensation arrangements.
Steam-power plants.
Submarine coal-mining.
Subsidences caused by mining-operations.
Surface-arrangements at mines.
Surveying.
Tin-mining.
Transport on roads.
Tunnelling, methods and appliances.
Utilization of dust and refuse coal.
Utilization of sulphureous gases resulting from metallurgical processes.
Ventilation of coal-cargoes.
Water as a motive-power in mines.
Water-tube boilers.
Watering coal-dust.
Water-incrustations in boilers, pumps, etc.
Winding arrangements at mines.
Winning and working of mines at great depths.

For selected papers, the Council may award prizes. In making awards, no distinction is made between communications received from members of the Institution or others.

TRANSACTIONS

OF

THE INSTITUTION

OF

MINING ENGINEERS.

THE MIDLAND COUNTIES INSTITUTION OF ENGINEERS.

ANNUAL GENERAL MEETING,

HELD AT UNIVERSITY COLLEGE, NOTTINGHAM, SEPTEMBER 2ND, 1905.

MR. G. ELMSLEY COKE, PAST-PRESIDENT, IN THE CHAIR.

The SECRETARY announced the election of the following gentlemen:—

MEMBERS—

Mr. GEORGE EDWARD BATEY, Colliery Manager, Clandown House, Clandown, Radstock.

Mr. EDWARD VINCENT CARDER, Mine Manager, Hafod Silica-mine, Minera, near Wrexham.

Mr. C. CHANDLEY, Mining Engineer, 120, Musters Road, West Bridgford, Nottingham.

Mr. THOMAS A. LAWTON, Colliery Manager, The Firs, Teversal, Notts.

Mr. WALTER M. REDFEARN, Mechanical Engineer, The Limes, Mansfield-Woodhouse.

ASSOCIATES—

Mr. DUNCAN BERNARD CHAMBERS, Assistant Manager, New Watnall Colliery, near Nottingham.

Mr. ERNEST LEE, Head Deputy, North Street, Riddings, Derbyshire.

STUDENT—

Mr. RAYMOND NADIN, Mining Student, 20, Ashby Road, Burton-upon-Trent.

The Annual Report of the Council, including the Abstract of Accounts, was submitted as follows:—

ANNUAL REPORT OF THE COUNCIL, 1904-1905.

The following tables shew the alteration in membership and the state of the finances during the last three years:—

	Year 1902-1903.	Year 1903-1904.	Year 1904-1905.
Honorary Members ...	15	15	16
Life Members ...	7	6	6
Members ...	259	275	283
Associate Members ...	3	3	4
Associates ...	59	62	59
Students ...	29	37	39
Totals ...	372	398	407

	£ s. d.	£ s. d.	£ s. d.
Cash receipts ...	477 14 9	631 5 0	567 14 6
Cash payments ...	450 8 6	651 0 2	546 3 0
Bank balance ...	199 9 1	179 13 11	201 5 5
Invested funds	640 0 0	640 0 0	640 0 0
Totals ...	£839 9 1	£819 13 11	£841 5 5

The finances of the Institution continue to improve, and, as shewn by the foregoing table, the balance in hand now amounts to £201 5s. 5d.

The following table shews the alteration in membership during the past twelve months, most of the resignations being caused by members ceasing to pay their subscriptions:—

		Less			Add		
	1903-1904	Dead.	Resigned.	Transferred.	Elected.	Transferred.	1904-1905
Honorary Members	15	—	—	—	1	—	16
Life Members ...	6	—	—	—	—	—	6
Subscribing Firm	1	—	—	—	—	—	1
Members ...	275	4	13	—	22	3	283
Associate Members	3	—	—	—	1	—	4
Associates ...	62	—	11	2	10	—	59
Students ...	37	—	1	1	4	—	39
Totals ...	399						408

The Annual Meeting of The Institution of Mining Engineers was held in Birmingham, in September, 1904: the attendance was satisfactory, and a large number of papers were read: the London Meeting took place in June, 1905.

Local meetings were organized as follows:—Nottingham, Annual Meeting, September 3rd, 1904; Nottingham, December 17th, 1904; and at Riddings Collieries, Alfreton, on May 2nd, 1905. On the last occasion the members were shewn round the collieries and pipe-works, and were kindly entertained by Mr. C. H. Oakes, jun., to whom, in addition to the firm of Messrs. James Oakes & Co., the thanks of the Council have been forwarded.

The Council regret that there has been an absence of any papers contributed by members of the Institution during the past twelve months. This they consider most unsatisfactory, and they would like to take this opportunity of inviting the contribution of suitable papers.

The influx of new members continues, and affords considerable satisfaction to the Council.

The Council wish to place on record the regret of every member of the Institution at the death of two of their number, Mr. C. Sebastian Smith and Mr. E. Lindley, both of whom have been warm supporters of the Institution for many years, and have rendered invaluable services.

THE MIDLAND COUNTIES
THE TREASURER IN ACCOUNT

Dr.

	£	s.	d.	£	s.	d.
281 Members, as per List, 1904-1905						
10 *less*, 6 Life Members, and 4 paid in advance						
271						
2 of whom paid 15s.	1	10	0			
269 Members at £1 11s. 6d.	423	13	6			
				425	3	6
3 Associate Members, as per List						
1 ,, ,, re-joined						
4 Associate Members at £1 11s. 6d.				6	6	0
99 Associates and Students, as per List						
2 of whom paid in advance						
97 Associates and Students at £1				97	0	0
2 Associates paid difference as Members and Entrance-fees ...				2	4	0
1 Associate to pay difference as Member and Entrance-fee ...				1	2	0
22 New Members and Entrance-fees						
7 *less*, paid in advance						
15 New Members at £2 12s. 6d.				39	7	6
14 New Associates and Students						
2 *less*, paid in advance						
12 New Associates and Students at £1				12	0	0
1 Attached Member				0	1	0
The Butterley Company				5	5	0
Subscriptions paid in advance:—						
7 Members	11	0	6			
5 Associates and Students	5	0	0			
1 New Associate Member	2	12	6			
4 New Associates and Students	4	0	0			
				22	13	0
Arrear-subscriptions as per List	79	1	6			
Arrears deemed irrecoverable, but since paid	9	9	0			
				88	10	6
				£699	12	6

Audited and found correct,

JOHN HALL,
JOHNSON PEARSON,
AUDITORS.

August 16*th*, 1905.

INSTITUTION OF ENGINEERS.

WITH SUBSCRIPTIONS, 1904-1905. Cr.

	Paid. £	s.	d.	Unpaid. £	s.	d.	Struck off List. £	s.	d.
225 Members at £1 11s. 6d.	354	7	6	......			......		
27 Members unpaid	... ..			42	10	6	......		
6 Members struck off	......			......			9	9	0
4 Members deceased	......			......			6	6	0
7 Members resigned	....			......			11	0	6
2 Members at 15s.	1	10	0	.. ...			......		
271									
4 Associate Members at £1 11s. 6d. ...	6	6	0	......			......		
62 Associates and Students at £1 ...	62	0	0	... ..			......		
23 Associates and Students unpaid ...	......			23	0	0	......		
4 Associates and Students resigned ...	......			......			4	0	0
8 Associates and Students struck off ...	... ..			......			8	0	0
97									
2 Associates paid difference as Members, etc.	2	4	0	......			......		
1 Associate to pay difference as Member, etc.	......			1	2	0	......		
15 New Members and Entrance-fees ...	39	7	6	......			......		
12 New Associates and Students ...	12	0	0	......			.. ...		
1 Attached Member	0	1	0	......			... ..		
The Butterley Company	5	5	0	......			......		
Subscriptions paid in advance	22	13	0	......			......		
	505	14	0	66	12	6	38	15	6
Arrear-subscriptions	29	1	6	17	15	0	41	14	0
	534	15	6	84	7	6	80	9	6
							84	7	6
							534	15	6
							£699	12	6

THE MIDLAND COUNTIES INSTITUTION OF ENGINEERS: ABSTRACT OF ACCOUNTS FOR THE YEAR ENDING JULY 31ST, 1905.

RECEIPTS.

	£ s. d.	£ s. d.
Balance in hand		179 13 11
225 Members at £1 11s. 6d.	354 7 6	
2 Associates transferred	3 3 0	
		357 10 6
4 Associate Members		6 6 0
60 Associates and Students		60 0 0
15 New Members and Entrance-fees		39 7 6
1 Attached Member		0 1 0
12 New Associates and Students		12 0 0
The Butterley Company		5 5 0
2 Transfer-fees		1 1 0
Subscriptions paid in advance		22 13 0
2 Members at 15s.		1 10 0
Sale of *Transactions*		13 13 6
Midland Railway debenture interest		15 4 0
Arrear-subscriptions paid		29 1 6
Bank interest		4 1 6
		£747 8 5

Audited and found correct,

JOHN HALL,

JOHNSON PEARSON,

AUDITORS.

August 16*th*, 1905.

EXPENDITURE.

		£ s. d.
Postages, parcels, telegrams, etc.		20 19 8
Stationery and printing		32 15 8
Books		12 0 0
Exchanges and binding		3 13 0
Hire of rooms for meetings		0 10 0
Reporting		5 0 4
Railway fares and expenses		12 9 4
Fees at meetings		0 17 6
Fire insurance		0 3 6
Subscription to Liége Congress		1 12 0
Auditors		3 3 0
Rent of room for library		2 10 0
Secretary's salary		100 0 0
The Institution of Mining Engineers:—		
Call 1904-1905:—Vols. xxviii. and xxix.	£323 19 0	
,, 1903-1904:—Vols. xxvi. and xxvii.	6 13 0	
Arrears	19 0 0	
		349 12 0
Bank commission and expenses		0 14 6
Cheque book		0 2 6
Balance in hand		201 5 5
		£747 8 5

Mr. G. Elmsley Coke moved the adoption of the report and statement of accounts.

Mr. W. G. Phillips seconded the resolution, which was carried unanimously.

ELECTION OF OFFICERS, 1905-1906.

The report of the Scrutineers (Messrs. E. O. Burrows and R. Blunt) was presented as follows:—

President:
Mr. W. G. Phillips.

Vice-Presidents:

Mr. G. H. Ashwin.	Mr. H. R. Hewitt.
Mr. G. C. Fowler.	Mr. T. G. Lees.
Mr. W. H. Hepplewhite.	Mr. J. Piggford.

Councillors:

Mr. P. Beaumont.	Mr. J. H. W. Laverick.
Mr. J. W. Fryar.	Mr. B. McLaren.
Mr. W. Hay.	Mr. B. Madew.
Mr. R. H. F. Hepplewhite.	Mr. J. Mein.
Mr. C. R. Hewitt.	Mr. E. D. Spencer.
Mr. J. P. Houfton.	Mr. J. T. Todd.

A vote of thanks was accorded to the Scrutineers for their services.

Mr. W. G. Phillips proposed a hearty vote of thanks to Mr. W. B. M. Jackson for the ability and dignity with which he had presided over the meetings of the Institution during the last twelve months.

Mr. A. H. Stokes (H.M. Inspector of Mines), in seconding the vote of thanks, said that the members were deeply indebted to Mr. Jackson for the many kindnesses that he had shown them during his term of office.

The resolution was carried amid applause.

The President (Mr. W. G. Phillips) then took the chair, and delivered the following address:—

PRESIDENTIAL ADDRESS.

BY W. G. PHILLIPS.

First of all, I must thank the members heartily and sincerely for having elected me as President for the ensuing year. I appreciate the great honour which you have conferred upon me, and although I am unconscious of any merit which would give me any claim upon your favour, I can say that during my year of office I will do the utmost that I can for the interests of the Institution. It is a pleasure to me to be able to congratulate the members upon the continued prosperity of the Institution, both as regards membership and its financial position.

During the past seven or eight years, the membership has been gradually increasing, and now numbers 407 members; and whereas some few years ago it was a difficult matter to make ends meet, we have now a very substantial balance at our bankers. This is a gratifying fact to the Council, as it frees them from anxiety, and enables them to work the Institute more fully to the advantage of its members than would otherwise be the case.

I notice in the report that a large number of Students and Associates are connected with this Institution. This, to my mind, is a most encouraging feature, and I hope that every member will do his utmost to increase their number.

The Student members are all young men in training for the responsible position of leaders in the great industry with which they are connected, and many of them are assisting to carry out important engineering works under the able guidance of their principals. Surely they can find something of interest to bring before the members; and as I cannot think that it is want of ability which prevents them, or even an overweening modesty, it must be the fear of harsh or unkind criticism which is barring the way. I feel sure that there need be no fear on this head, as

every member of this Institution would always give the most generous encouragement to the efforts of the youngest of our Student members. Let me therefore appeal to them to come forward, and contribute to the usefulness of the Institution to which they belong.

I think that the Institution performed a useful work last year in advising the County Councils of Derby and Nottingham with respect to the lectures which were given by Mr. G. Blake Walker, and you will be pleased to know that the Advisory Committee is trying to arrange a series of lectures for the coming winter on electricity and the distribution of electric energy, while the Council to-day have discussed arrangements for a series of lectures on sinking shafts.

There has been latterly much discussion about the alleged backwardness of this country in the matter of technical education, and the necessity for the higher training of our engineers and workpeople; and we have had it dinned into our ears with such pertinacity that the charge has become monotonous, that this country cannot hold its own with its competitors because of the technical ignorance of our people.

Some mining engineers, for whose opinion generally I have a high regard,—have shared this feeling to some extent, with reference to the education of the mining engineers of this country. Indeed, I too share these feelings, to a very limited extent, as applied to the manufacturing industries of this country. But I have an abiding faith in the ability of the British workman to hold his own in a fair race, and if the British manufacturer be given an equal chance, in the production and disposal of his products, I think that those countries who are held up to us as paragons will find that we are not much behind.

When, however, these criticisms of comparison are made to apply to our mining engineer, I entirely disagree with them. By his works you must judge him; and I venture to say (nowhere more than in this eastern coal-field) that he has shown himself capable of dealing with the most difficult engineering problems in the most masterly manner. In no country in the world is coal-mining carried on with a greater degree of safety to life and limb than in this country; and in this Midland mines-inspection district particularly. I maintain that the British mining engineer is always to the front, and one of the

principal obligations of an Institution such as this is to keep him there. The lectures, to which I have referred, are calculated to do much in this direction, and I wish them every success.

The conclusion of the labours of the Royal Commission on Coal-supplies marks an epoch in the history of the mining industry of this country; and its report and the voluminous evidence on which it is founded testify to the thorough and exhaustive manner with which the Commission have discharged the important duties assigned to them.

The pre-eminence of this country amongst the industrial nations of the earth depends so much upon an unlimited supply of fuel, that it must be gratifying to every one to know that the exhaustion of our British coal-fields is relegated to the dim and very distant future; and, consequently, that there is no reason to be alarmed as to a comparatively early collapse of our manufacturing supremacy on that account. Still there is much food for thought when we consider what is involved in carrying on mining operations at a depth of 4,000 feet, and that seams of coal, down to 12 inches in thickness, have been included as workable seams in the report of the Commission. I believe, however, I am right in stating that between 70 and 80 per cent. of the total quantity of ungotten coal exists in seams of a thickness of 2 feet and over; but even with this comforting fact before me, I feel convinced that when half the suggested workable depth-limit becomes the average working depth of the collieries in this country, we shall witness a higher nominal selling price of coal than at present exists, if coal-mining is to yield a profit to those who invest their money in it.

There can be no doubt that, at depths of over 2,500 feet, the costs of working will be materially increased, notwithstanding that something may be done in mitigation by the more extended use of coal-cutting machinery and other labour-saving appliances. The use of machinery for coal-cutting is becoming more general and its adoption, in those seams where the conditions are favourable, should largely modify the conditions of deep mining, rendering possible the production of a given quantity of coal from much less pit-room, consequently reducing the lengths of roadways and faces to be kept open, and making the ventilation of the pit a much easier matter.

In the Midland mines-inspection district, I find that during the past two years the number of machines at work has increased from 40 to 56, electrically-driven machines finding the greater favour. The average output of each of these machines is 19,275 tons per annum. Table I. records figures relative to the produce of coal-cutting machines in use in the coal-fields of this country; and the results vary so greatly, as almost to suggest a difference in the basis upon which the returns are made. The coal-output wrought by machinery is 2·88 per cent. of the total output of Great Britain. In the Midland mines-inspection district, 3·64 per cent. is cut by machinery; and in the Yorkshire district, 6·76 of the output is so produced.

TABLE I.—COAL-OUTPUT BY MACHINERY IN GREAT BRITAIN.

Name of Mines-inspection District.	No. of Machines.	Coal-output. Tons.	Coal-output per Machine per annum. Tons.
East of Scotland	75	730,669	9,742
West of Scotland	95	968,473	10,194
Newcastle-upon-Tyne	47	401,688	8,547
Durham	73	508,392	6,964
Yorkshire	101	1,949,119	19,300
Lancashire	46	219,496	4,771
Liverpool	91	581,270	6,387
Midland	56	1,079,389	19,275
Stafford	22	218,524	9,933
Cardiff	9	40,986	4,554
Swansea	...	...	...
Southern	3	6,553	2,184
Totals	618	6,704,559	10,846

At the colliery with which I am connected, the conditions are not favourable to the use of machines, and I have no personal experience of their use; but I am so struck with the wide difference of production, as given by the reports of H.M. inspectors of mines, that I submit the figures for your consideration. I hope that we shall receive some interesting papers giving the results of working in this district, and possibly the wide discrepancy, to which I have drawn your attention, will be satisfactorily explained.

The enquiry of the Royal Commission ranged over many subjects, all of great importance to coal-mining, and it would be utterly impossible for me to do justice even to a few of them on

such an occasion as this. The question of greater economy in the production and use of steam, the preparation of coals for the market, the gasification of fuel and the collection of bye-products, and particularly the important evidence which was given as to the conditions attending coal-mining in this country and on the Continent, at a depth approaching the limit on which the calculation of our existing coal-supplies has been made, are all deserving of and will no doubt receive the attention of those connected with mining in this country.

I think that the question of the transport of coal from the working-face to the main system of haulage, or what may be termed secondary haulage, at a large colliery is one of the utmost importance; and should receive the greatest attention from those responsible for the setting-out and working of mines. The question of main-road haulage has been grappled with, and there are few collieries which do not possess some system of main-road mechanical haulage suitable to the special conditions for which they have been established; but the question of mechanical secondary haulage has not received that attention which its importance demands, and it is still very largely effected by means of horses and men. From the facility with which power can be electrically transmitted, I feel very strongly that there is ample room for improvement here; and I would like to see the day when a horse or pony will be a rarity in a coal-pit. I hope that the subject will receive the attention of the members, and that descriptive papers will be received for discussion during the coming year.

I wish that I could have congratulated you upon a healthy and profitable condition of the coal-trade; but that long-looked for, often promised revival of the general trade of the country, which is necessary for the prosperity of the coal-trade, has not yet arrived; prices remain low, and profits are not so satisfactory as we should like to see them. There can be no doubt that trade is improving, even if slowly. The cotton, woollen and other textile trades are healthy, the engineering trade is moving, and even shipbuilding is better, and although prices do not improve much in the iron-trade the demand is better, and prices as a natural sequence will rise. If this improvement continues, it will soon have a beneficial effect on the coal-trade, and it will again see brighter days.

These are the times when your practical knowledge, enlarged by your association with this Institution, comes to your aid, and assists you in the development of economic schemes to keep down the cost of producing a ton of coal, and when your powers of application and organization are put upon their trial. I believe, in fact, that these times of adversity are useful to us, and form an excellent tonic. We are apt to become fretful if the course is continued too long, however, and we begin to think that there is something radically wrong with the country and that drastic remedies are required.

Well, I am not one of those who think that the country is going to the dogs; to me its future seems as great or greater than its past, providing that we hold fast to the traditions which have made us the greatest and the freest nation upon earth. If, however, our industries are to be bound and trammelled by legislative enactments, dictated by sentiment and not built upon a foundation of sound practical commonsense, if the government of the country is to say to a grown man, that he must not work more than eight hours out of twenty-four; then I should begin to think that our chances were going, that we should soon pass our meridian, and that some other nation more sensibly governed would grasp the proud position which is now ours. I cannot think, however, that anything so suicidal, and so detrimental, to the interest of the working classes of this country, is likely to be enacted in our time; but of whatever folly our legislators may be guilty in the future, it is necessary that you should keep in front of your profession in order to obtain the highest results from your labours. This position will be more readily attained and more securely held by giving your active support to this Institution, and by helping in the educative work which it was the intention of its founders that it should accomplish.

I am afraid that the few remarks which you have permitted me to make hardly deserve the dignified title of a "Presidential Address," but I know that you will not be hypercritical, and whatever may be my shortcomings in this matter, I will try to compensate for them by a strenuous devotion to the interests of the Institution during the coming year.

Mr. M. Deacon (Sheepbridge), in moving a vote of thanks to the President for his very able address, said that he had raised several important questions, which it was not usual to discuss upon a presidential address.

Mr. J. T. Todd (Blackwell), in seconding the resolution, said that Mr. Phillips had referred to many interesting topics, and it would be well for the members to consider them very carefully. He thought that it would be easy to account for the differences in the average output of coal-cutting machines in various parts of the country. The stoop-and-room system of Scotland and the bord-and-pillar system of the North of England permitted very different results for coal-cutting machines from the longwall system of the Midlands; and a heading machine would not produce so large an output as a longwall machine.

He (Mr. Todd) was interested in a remark made by Mr. Phillips as to the time when horses and ponies would be dispensed with in collieries. An eminent gentleman, lecturing in that building, and referring to the day when they would be compelled to work extremely thin seams, had suggested that a certain size of dog would haul the tubs along the roads. He was sure that the members would like that day to be deferred as long as possible. In concluding, he hoped that the observations of Mr. Phillips on the eight-hours' question would be borne in mind by the members.

The resolution was heartily adopted.

Mr. W. Maurice read the following paper on "A Spark-arrester for Locomotives":—

A SPARK-ARRESTER FOR LOCOMOTIVES.

By WILLIAM MAURICE.

The object of this paper is to introduce an invention,* which has been designed to prevent the emission of sparks from locomotive-chimneys.

The device consists of a vertical cage, composed of a series of bars arranged in a circle. The bars are set at varying angles, in order that the products of combustion from the furnace may strike against them and be diverted before they pass into the direct updraught. Any sparks that may be carried are intercepted and fall to the bottom of the cage. This cage is

FIG. 2.

FIG. 1.

FIG. 3.

FIGS. 1, 2 AND 3.—THE YOUNGER SPARK-ARRESTER FOR LOCOMOTIVES.

fitted between the bottom of the smoke-box and the base of the chimney. Fig. 1 is a section through the smoke-box of a locomotive, showing the spark-arrester in place. Fig. 2 is an elevation of the spark-arrester, viewed from the side opposite to that from which Fig. 1 is taken; and Fig. 3 is a sectional plan.

* British Patent, 1904, No. 12,686, Mr. James Younger.

The spark-arrester is shown in two parts, each consisting of end-flanges or plates, A and A^1: the flanges A^1 being bolted together to form the complete cage. Between the flanges are fixed vertical bars, B, which (as shown more especially in the plan) are placed at varying angles to a radius of the cage, affording channels between them for the free entrance of the hot gases.

The front blade, B^1, is set, for convenience, at right angles to a radius, as is also the larger double blade, B^2, fitted at the side next to the ends of the fire-tubes.

It will be noticed that the hot gases, coming from this side, cannot directly enter the tubular cage, but meet the faces of the blades, B and B^2. Consequently, any sparks carried with them are caught, and fall to the bottom of the smoke-box, C, within which the cage is secured.

An arrester of the type described was applied to a colliery-locomotive about four months ago. The engine-drivers had been instructed to make daily efforts to produce sparks, and had been supplied with all kinds of fuel, with the object of giving the arrester a thorough test. Previous to the application of the arrester, sparks and fine cinders were frequently emitted from the chimney, and occasionally proved a source of eye-troubles to drivers and firemen. They report that neither dust nor sparks now escape, and it is noticed that the coal-consumption per ton-mile averages about 10 per cent. less than before. It is probable that this latter result has been brought about by the arrester causing more uniform distribution of the draught.

It is known that certain of the locomotive-tubes always became choked, and required much more cleaning than others; whereas each tube now seems to be doing its share of the work, and all are cleaner at the end of a shift than they were before the arrester was used.

Mr. James Younger, the experienced engine-driver who has patented this invention, is to be congratulated on the success of this initial trial, and it is hoped that the device will prove equally effective when used on a larger scale.

Mr. G. Elmsley Coke said that Mr. Maurice had described an attempt to minimize the serious losses due to sparks from locomotives. He had noticed lately the large number of bare patches in fields adjacent to the railways, caused no doubt by sparks from passing locomotives. If this device prevented the emission of sparks and at the same time reduced the consumption of coal, it would probably be adopted very quickly.

Mr. M. Deacon said that he did not propose to criticize the appliance mechanically, but he was very sorry indeed to hear that it was going to reduce the consumption of locomotive-coal by 10 per cent., although no doubt from the point of view of a railway-company that was a very important matter. A Bill had been laid before Parliament which had not quite struggled through last session, by which railway-companies were to be held responsible for all or any damage which might be done to growing crops by sparks from their engines. Hitherto, the liability had been limited to the absence of proper precautions on the part of a railway-company, but this Bill proposed to render the railway-companies liable, whether proper precautions had been taken or not. The invention described in Mr. Maurice's paper would be a very valuable means of reducing the liability under that Bill, should it be passed.

Mr. B. McLaren (Pye Hill) remarked that at a colliery of which he was manager, some time ago, the sparks from a small locomotive running about the colliery-yard set fire to the frames on which the pulleys rested, and had the smoke not been observed by the winding-engineman, the whole of the head-gear would probably have been destroyed. At the same colliery, another fire on the pit-bank occurred, more recently, from the same cause. Two years ago, at another colliery, an engineman noticed, about 1 a.m., sparks falling on to the ground from the heapstead, at a height varying from 20 to 30 feet. He went for the fire-extinguishing apparatus, and soon put out what would probably have developed into a disastrous fire. When he (Mr. McLaren) arrived at the colliery on the next morning, he examined the electric wires to see if the fire had arisen from a short circuit, but he could find no trace of anything of the kind. Moreover, no one had been about the place, from 4 p.m. on the previous day, and the electric lights had not been used. The locomotive had, however, been running about the colliery-

yard until 6 p.m., emitting numerous sparks; and his investigations convinced him that some sparks had blown through a broken glass window upon some material deposited at the side of the coal-tippler on the floor, that it had smouldered for seven hours, and that it had ultimately set the pit-bank on fire. About 25 square feet of the flooring were burnt. If the fire had occurred, say, on a Saturday night, the whole of the pit-top would, in all likelihood, have been destroyed. These instances showed that this invention would prove very useful to colliery-owners, as well as to railway-companies.

The PRESIDENT (Mr. W. G. Phillips) believed that the spark-arrester was likely to prove valuable, but he was doubtful as to what effect it would have on the accumulation of dust. He thought that the arrangement of vertical bars round the exhaust-pipe would possibly facilitate the accumulation of dust, and so cause some interruption of the draught; but if that were not the case, the invention could be unreservedly commended. At the colliery with which he was connected, there was an incline of 1 in 48, and, two years ago, the underwood at the side was set on fire by sparks from a locomotive, and three acres of it were destroyed. He did not quite see how the appliance could effect a saving of 10 per cent. in the coal-consumption; and, like Mr. Deacon, he thought that, under the existing conditions of trade, it would be a misfortune to some of them if such a saving were effected. He moved a vote of thanks to Mr. Maurice for his paper, and hoped that he would inform the members, when the invention had had a longer and more general trial, whether it was as useful as its inventor thought that it would be.

The resolution was unanimously approved.

Mr. MAURICE, replying to the discussion, said that the appliance was fitted to the heaviest locomotive available, and he was glad to be able to state that its use had proved advantageous in many ways. There was now no emission of cinders or sparks, the firemen had less stoking, and the work of the cleaners was also lessened. He did not expect, however, that the appliance would effect a saving in coal-consumption, except when applied to an engine, which worked in a manner similar to that he had described.

MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.

ANNUAL GENERAL MEETING,

HELD IN THE LITERARY AND PHILOSOPHICAL SOCIETY'S ROOMS, LEOPOLD STREET, SHEFFIELD, JULY 25TH, 1905.

MR. J. R. ROBINSON WILSON, VICE-PRESIDENT, IN THE CHAIR.

The minutes of the previous General Meeting were read and confirmed.

Messrs. C. Creswick and G. B. Stones were appointed scrutineers of the balloting-papers for the election of officers, and also for representatives on the Council of The Institution of Mining Engineers for 1905-1906.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. RICHARD RAYMONT CAME, Mining and Metallurgical Engineer, Woodhall Spa, Lincolnshire.

Mr. WILLIAM HEPBURN, Assistant Manager of Engineering Works, 150, Beeston Road, Leeds.

Mr. MARK RHODES, Mining Engineer, Monckton Main Colliery, Barnsley.

Mr. W. WALKER, H.M. Inspector of Mines, Doncaster.

The Annual Report of the Council, and the Statement of Accounts for the past year were read as follows:—

ANNUAL REPORT OF THE COUNCIL, 1904-1905.

The Council has pleasure in presenting to the members of the Institute its annual report.

The number of members for the last two years is as follows:—

	1903-1904.	1904-1905.
Life Member	—	1
Members	273	264
Associate Members	10	10
Associates	10	11
Students	12	16
Totals	305	302

The table shows an apparent decrease in the number of members of 3 during the year. The above figures, however, do not include 5 members whose subscriptions were received after June 30th, making the total number of subscribing members 307.

At the date of closing the accounts for the year, 19 subscriptions were owing; and deducting 5 since received, there is at present £21 owing from 14 members.

The following arrears of subscriptions have been paid during the year:—1899-1900, £1 10s.; 1900-1901, £1 10s.; 1901-1902, £3; 1902-1903, £3; and 1903-1904, £10 10s.: a total of £19 10s.

The Council regrets to announce that 3 members have died during the year, namely:—Dr. Schultz, Messrs. F. Bagshaw and W. J. S. Batey, and that 9 members have resigned.

The balance in the bank is £243 1s. 4½d., as compared with £240 8s. 1d. at the end of last year. There are, however, outstanding accounts to the value of £17 12s. 1d., making the actual balance £225 9s. 10½d. The Council considers this very satisfactory, in view of the heavy expenditure entailed in removing the head-quarters of the Institute to Sheffield.

The following papers have been read:—

"The Automatic Prevention of Over-winding of Hoisting, Winding and Haulage-engines or Motors." By Mr. J. S. Barnes.

"Systematic Timbering at Emley Moor Collieries." By Mr. H. Baddiley.

"A Safety Catch for Cages." By Mr. J. Clegg.

"Notes and Considerations on Systems having Work of an Intermittent and Irregular Character to Perform: Methods of Load-compensation." By Mr. Maurice Georgi.

"The Work of a Joint Colliery Rescue-station." By Mr. M. H. Habershon.

"Notes on Capels for Winding-ropes." By Mr. T. W. H. Mitchell.

"Presidential Address." By Mr. T. W. H. Mitchell.

"The Dust-danger." By Mr. W. H. Pickering.

"A Colliery-plant: its Economy and Waste." By Mr. A. J. Tonge.

"The Utilization of Surplus Gases from Bye-product Coke-ovens." By Messrs. G. Blake Walker and L. T. O'Shea.

"The Effect of Watering of Coal-mines on the Spread of Ankylostomiasis." By Mr. Jonathan Wroe.

This shows a satisfactory increase in the number of papers as compared with last year, but the Council would remind the members that it has only been obtained at the cost of frequent appeals and great labour. The Council feels strongly that this should be unnecessary, and members would relieve it of the anxiety which it experiences in this respect, if they would voluntarily offer papers for discussion.

The Council, being of opinion that the facilities for the discussion of papers read before this and other Institutes are insufficient, has decided that one or two meetings in the year shall be set apart for discussions.

Mr. T. W. H. Mitchell, having been elected to the Presidency of the Institute, resigned the offices of Secretary and Treasurer, which he had held for 14 years. The Council desires to place on record its high appreciation of the valuable and disinterested services which he has rendered to the Institute whilst holding these offices, and in thanking him for those services it wishes him a successful term as President.

Mr. L. T. O'Shea was appointed Secretary and Treasurer in succession to Mr. Mitchell, and in consequence, the headquarters of the Institute have been removed to Sheffield. An agreement has been entered into with the Sheffield Literary and Philosophical Society for the use of one of its rooms in Leopold Street as a Council-room and Library, and for the use of its Lecture-room for the meetings of the Institute.

The Library has been transferred to Sheffield, and the books placed in bookcases. It is open to members daily from 11 to 6 (Saturdays 11 to 1), when books may be consulted or borrowed on applying to Mr. S. Johnson at the Society's Room.

It is with pleasure that the Council records the gift to the Library, by Mr. W. E. Garforth, of 20 bound volumes of the Reports of H.M. Inspectors of Mines, and tenders to him the hearty thanks of the Institute.

Three hundred and fifty copies of *An Abstract of the Report of the Prussian Commission on Falls of Stone and Coal* have been purchased by the Council and presented to the members free of cost.

In the report for last year, the Council announced its desire to tabulate the various strata that had been proved in the Yorkshire district. The Committee appointed to carry out this work has made considerable progress, and the Council desires to thank those members of the Institute and others, who have contributed records of sections, for their valuable co-operation and assistance. It is further able to announce that The Midland Counties Institution of Engineers has consented to co-operate with your Committee and supply sections of the Nottinghamshire and Derbyshire districts. This will greatly increase the value of the publication, and make it a record of the whole coal-field.

DR. **THE TREASURER (Mr. L. T. O'SHEA) IN ACCOUNT WITH THE MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS, 1904–1905.** CR.

	£	s.	d.	£	s.	d.
July 1st, 1904.						
To Balance at bankers'	240	8	1			
„ Cash in Treasurer's hands	2	11	3½			
				242	19	4½
June 30th, 1905.						
To Subscriptions for 1904-1905, 298 at £1 10s.	447	0	0			
„ Arrears, 1903-1904, 7 at £1 10s. ...	10	10	0			
„ „ 1902-1903, 2 at £1 10s. ...	3	0	0			
„ „ 1901-1902, 2 at £1 10s. ...	3	0	0			
„ „ 1900-1901, 1 at £1 10s. ...	1	10	0			
„ „ 1899-1900, 1 at £1 10s. ...	1	10	0			
„ Subscriptions paid in advance for 1905-1906, 1 at £1 10s.	1	10	0			
„ Life-subscription, 1 at £30	30	0	0			
				498	0	0
„ Sale of dinner-tickets, 121 at 5s. ...	30	5	0			
„ Wine account	7	1	8			
				37	6	8
„ Sale of *Transactions*, and authors' copies				1	2	0
„ Sale of furniture...				2	1	6
„ Letting of room				1	0	0
„ Bank interest				8	17	2
				£791	6	8½

Examined and found correct,

M. H. HABERSHON, } AUDITORS.
THOMAS GILL, }

July 15th, 1905.

	£	s.	d.	£	s.	d.
June 30th, 1905.						
By The Institution of Mining Engineers:—						
Call of 19s. per Member on 294 Members	279	6	0			
„ „ for 1903-1904, 7 at 19s.	6	13	0			
Excerpt *Transactions*, etc.	11	1	0			
„ Report of the Prussian Commission on Falls of Stone and Coal	10	10	0			
„ Authors' copies	2	0	0			
„ Binding	0	2	3			
				309	12	3
„ Annual dinner				44	13	4
„ Printing and stationery				37	1	5
„ Rent of rooms				22	12	6
„ Reporter				6	15	0
„ Insurance				1	11	6
„ Cleaning				1	19	0
„ Hire of rooms for meetings at Sheffield and Leeds				3	3	0
„ Secretary's salary:—						
T. W. H. Mitchell	16	13	4			
L. T. O'Shea	33	6	8			
				50	0	0
„ Secretary's expenses				2	14	0
„ Stamps, telegrams, carriage, etc.				17	7	9
„ Telephone-rent				8	10	0
„ Bookcases				34	0	0
„ Removal and arranging library				8	5	0
„ Balance at bankers'	£242	2	11			
„ Cash in Treasurer's hands	0	19	0½			
				243	1	11½
				£791	6	8½

MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS: GENERAL STATEMENT, 1904-1905.

LIABILITIES.

1905.		£ s. d.	£ s. d.
June 30th.—To Creditors:—			
,,	,, Calls	13 6 0	
,,	,, Exchanges...	3 10 9	
,,	,, Electric Light	0 15 4	
			17 12 1
,,	,, Balance, being capital, as at June 30th, 1904 ...	611 11 4½	
,,	,, Increase since	22 19 6	
			634 10 10½
			£652 2 11½

Examined and found correct,
M. H. HABERSHON,
THOMAS GILL,
AUDITORS.

July 15th, 1905.

ASSETS.

1905.		£ s. d.	£ s. d.
June 30th.—By Cash at bank		242 2 11	
,,	,, ,, in Treasurer's hands	0 19 0½	
			243 1 11½
,,	,, Bookcase (cost)		34 0 0
,,	,, Value of 7,213 parts of *Transactions*, at 1s.		360 13 0
,,	,, Value of 115 copies of Narrative of Sudden Outbursts of Gas, at 1s. ...		5 15 0
,,	,, Value of 116 copies of Committee's Report on Safety-lamps, at 1s. ...		5 16 0
,,	,, Value of 16 copies of Report of French Commission on Use of Explosives, at 3s.		2 8 0
,,	,, Value of 9 copies of Report of the Prussian Commission on Falls of Stone and Coal, at 1s.		0 9 0
			£652 2 11½

Mr. M. H. HABERSHON moved the adoption of the Report and of the Accounts.

Mr. I. HODGES seconded the resolution, which was adopted.

ELECTION OF OFFICERS, 1905-1906.

The SCRUTINEERS reported the result of the ballot, as follows:—

PRESIDENT:

Mr. T. W. H. MITCHELL.

VICE-PRESIDENTS:

Mr. M. H. HABERSHON.	Mr. ISAAC HODGES.	Mr. J. L MARSHALL.

COUNCILLORS:

Mr. THOMAS GILL.	Mr. ROSLYN HOLIDAY.	Prof. G. R. THOMPSON.
Mr. P. GREAVES.	Mr. HARRY RHODES.	Mr. W. WALKER.
Prof. F. W. HARDWICK.	Mr. THOMAS STUBBS.	Mr. W. WASHINGTON.
Mr. WALTER HARGREAVES.	Mr. E. W. THIRKELL.	Mr. J. R. R. WILSON.

REPRESENTATIVES ON THE COUNCIL OF THE INSTITUTION OF MINING ENGINEERS, 1905-1906.

Mr. W. H. CHAMBERS.	Mr. T. W. H. MITCHELL.	Mr. J. NEVIN.
Mr. W. E. GARFORTH.	Mr. H. B. NASH.	Mr. G. B. WALKER.
	Mr. J. R. R. WILSON.	

DISCUSSION OF MR. A. HASSAM'S PAPER ON "THE TAXATION OF COLLIERIES."*

Mr. H. B. NASH thought that the anomalies in matters of colliery-rating, brought to notice, furnished proof that something might be done by Institutes like their own, to force the hands of rating authorities, and to place the matter on a more satisfactory footing than was the case at present. All who were connected with collieries, if they attempted anything to reduce their costs, knew that they ran the risk of increasing the rates, and this was generally done in cases where the oppression was most severe. Mr. Hassam stated in his paper that in 145 unions there were 2,085 mines, and no less than sixteen different systems of rating; and that in Cheshire the average gross rate-

* *Trans. Inst. M. E.*, 1905, vol. xxix., page 90.

able value was 7·03d. per ton, and in Derbyshire, 2·09d. per ton.* He (Mr. Nash) suggested that some more uniform system should be adopted, whereby, at least, different counties might be treated on a common basis, instead of the wide diversity between 7d. and 2d. per ton, and where, probably, there was little difference in the value of the coal. The Denaby colliery rating-appeal case, of a few years ago, was yet in their memory, whereby an effort was made to arrive at the rateable value of the colliery in the same manner as that of gas-works and railways. The costs involved in that case, however, were so great that no other attempts were made to get the rateable value reduced: the feeling being that the costs would exceed any relief likely to be obtained.

Mr. M. H. Habershon thought that the method of rating, of which an example was given,† would provide a means whereby a fair valuation of a colliery could be calculated, as it enabled deductions to be made at certain collieries for expenses which did not exist at other collieries; but it would be difficult to apply in many cases. He thought that the method of valuation based on the royalties was, at any rate, a convenient one, especially in those cases where collieries were working coal in several adjoining townships. It was most important, however, that the surface-plant should not be taken at too high a valuation, and he thought that it was a matter in which a great amount of consideration was required. A colliery with a pumping-plant, was liable to be called upon to face an increased valuation in consequence of having installed this plant, which, as a matter of fact, was an incubus upon the concern instead of a source of profit.

Mr. John Wainwright thought that the rateable value of a colliery should be based upon its output, irrespective of the value of the machinery used in winning the coal. The thickness of the seam and the commercial value of the coal were important factors in assisting rating authorities, if only they would consider them, because for the same output, the area worked of a thin seam was large compared with that of a thick seam, and the working costs were higher in the case of the thin seam. It was

* *Trans. Inst. M. E.*, 1905, vol. xxix., pages 98 and 100.

† *Ibid.*, pages 103 and 104.

manifestly unfair to take the plant and buildings as a basis for rating, as one colliery might find it necessary to make a large capital-outlay on a pumping-plant, which might drain the surrounding district and so relieve other collieries of that expense. If this were used by the rating authority as a basis for the rateable value, it was very unfair, because that colliery had not only provided the plant, but it had also found the water to be pumped. Further, neighbouring collieries might be situated in parishes where a cheap supply of electricity from some large electrical power-company might be available; in that case it would not be necessary for those collieries to provide so large a plant. All this brought one back to the fact that the output should be the basis for rating, and not the buildings and machinery.

He thought that it would be very much better for both rating authorities and ratepayers if a statutory basis could be fixed, so that all collieries would be rated upon like methods. He suggested that Parliament should be approached upon the matter by both sides, with a view to the establishment of a more uniform system of rating. A board appointed for each mines-inspection district, with power to fix the rateable value of collieries upon some statutory basis, would be a better authority than the present system of Assessment Committees.

The discussion was adjourned.

DISCUSSION OF MR. W. H. PICKERING'S PAPER ON "THE DUST-DANGER."*

Mr. W. Walker (H.M. Inspector of Mines) referring to his description of the firing of dust by gas-flames at the bottom of a shaft,† said that the shaft was about 1,680 feet deep, and, until some seven or eight years ago, the shaft-bottom was lighted by open gas-lights. The shaking-screens and belts were placed close to the top of the downcast-shaft. The coal-dust was carried down by the air from the screens, and ignited at the open lights to such an extent that the flame was sometimes carried for a considerable distance. The danger of fire and of the ignition of coal-dust in the mine was apparent; and, consequently, the

* *Trans. Inst. M. E.*, 1905, vol. xxix., page 134. † *Ibid.*, page 140.

open lights were removed and replaced by electric incandescent lamps; and the other measures, which he had described,* were taken to prevent coal-dust from descending the shaft. He believed that several firms in the Yorkshire mines-inspection district were considering the question of removing the dust from the screens. At one colliery it was proposed that the screens and tipplers should be enclosed, and that fans should be employed to draw the coal-dust from the screens and pass it into a cyclone-collector, where it would be damped with steam. Much had been said about the bad effect of water upon certain stones in mines, and, to a certain extent, this was true; but he felt that the ill effects had been overrated. In the discussion upon a paper by Mr. Cresswell Roscamp on an improved apparatus for laying dust in coal-mines, Mr. A. A. Atkinson, chief inspector of coal-mines in New South Wales, suggested that a committee should be appointed to investigate and report upon the best means of dealing with, what Mr. Pickering appropriately called, the dust-danger. He agreed with that suggestion, and he had no doubt as to the necessity of adopting, in many mines, up-to-date methods of dealing with dust.

Mr. M. H. Habershon said that Mr. Pickering pointed out that permitted explosives were only relatively safe. In his recent report, Captain A. P. H. Desborough† stated that the only guarantee which one could take from the fact that an explosive had passed the special test, was that it was safer than gunpowder. The members of the Institute, for some time past, had felt that there should be some means of testing explosives, under the same conditions as when used in pits. The subject was at present in abeyance, but he thought that Mr. Pickering's remark, coupled with what was stated in the report to which he had referred, should bring the matter strongly forward again; and he hoped that, sooner or later, it would be possible for mining engineers to test, say, 16 ounces of explosive in a manner analagous to the conditions met with in mines. Mr. Pickering also stated that it was not necessary for screening-plant to be placed contiguous to the pit-bank; and in several Continental coal-fields this danger had been recognized for some time past.

* *Trans. Inst. M. E.*, 1905, vol. xxix., page 140.

† *Twenty-ninth Annual Report of H.M. Inspectors of Explosives: being their Annual Report for the Year 1904*, 1905, [Cd. 2595], page 142.

He thought that it should be borne in mind that, in addition to guarding against the danger from dust, the screens should be placed as far away as possible from the pit-top, so that, in case of fire, there could be no danger of fumes and smoke being carried down the downcast-shaft.

Mr. L. T. O'SHEA said that a Joint Committee appointed by the Midland Counties Institution of Engineers and the Midland Institute of Mining, Civil and Mechanical Engineers, were unanimously of opinion that an explosives testing-station should be erected, and that there was great necessity for it, but it was found difficult to meet the question of expense. There had been a joint meeting of representatives of the Institute, the Leeds University, and the, then, University College of Sheffield, to see what could be done with regard to taking active steps to erect a testing-station. The method by which funds could be raised for the erection of a station was discussed; but the matter went no further, as the opportunity for obtaining the necessary money did not seem a favourable one. The amount required to erect a testing-station, such as would enable them to obtain the information which Mr. Habershon had mentioned, would range from £1,800 to £2,000.

The method of testing explosives at Woolwich placed all explosives that passed the test on the same level as regards their safety in the presence of gas; and the results of the experiments did not indicate to the consumer which were the safest explosives to use.

He had no doubt, however, that if a station, such as had already been described in the *Transactions*,* were erected, the information obtained would well repay those who had contributed to its erection. If funds were forthcoming, the mining department of the University of Sheffield was prepared to give every assistance in its power.

Mr. H. RHODES thought that Mr. Pickering had found the key to the situation, when he said that the only radical way of keeping mines free from dust was by cutting off the supply. There were one or two methods by which this could be done to a great extent. One was by placing the screens a sufficient distance away from the pits, so as to prevent the fine dust from

* *Trans. Inst. M. E.*, 1897, vol. xiv., page 411.

the screening-operations from being taken down into the mine by the intake-air. Another method, by which a great deal could be prevented, was by using impervious bottoms and sides to the tubs. In his opinion, a great deal of dust was produced by small coal, falling through interstices in the tub-bottoms, being crushed into impalpable dust by the passing of men and animals.

With respect to the laying of dust, he had been surprized at the effect of salt-water upon dust in a deep mine, where the temperature in the return-airways was 84° Fahr. In this mine, the pit-water was very salt, and although the roads were very dry, comparatively little dust was found in them, when distant more than about 1,500 feet from the shaft-bottom. It had been proved that the addition of salt to the slaking water had a marked effect at Continental collieries, and he thought that this was the reason why these workings of this colliery were also, to a great extent, free from dust. The conditions for making dust were very favourable, here, as the difference between the wet-bulb and dry-bulb thermometers was as much as 5½° Fahr. The effect of injudicious watering was very marked at this colliery, and great trouble was experienced from the floor lifting, whenever a water-pipe burst or a tub of water was overturned.

The Chairman (Mr. J. R. R. Wilson) thought that coal falling through the interstices of the bottom and sides of the tubs was undoubtedly the chief source of dust, but a certain amount was also blown from the tops of the tubs. His own suggestion (frequently reiterated) of preventing the dust from passing on to the roads was (1) to catch it at both ends before it came to the roads, and (2) to prevent it from going down the shaft. Some years ago, Mr. E. W. Thirkell tried the experiment at the Oaks colliery, of spraying the tubs, and it proved very effective. The question had been raised that, if the tubs were watered, the tare of the tubs should be altered; but he thought that a short trial would soon enable them to ascertain the amount of water to be used, in order that all might be evaporated by the time that the tubs reached the screens.

The discussion was closed.

MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.

EXCURSION MEETING,
AUGUST 20TH, 1905.

THE YORKSHIRE ELECTRIC POWER COMPANY: THORNHILL POWER-STATION.

The Yorkshire Electric Power Company is authorized to supply electrical energy over an area of 1,800 square miles, taking in the whole of South Yorkshire. The Thornhill power-station is one of the four which are to be erected. Current is generated and transmitted at a pressure of 10,000 volts, and transformed to 2,000 and to 400 volts at the consumers' terminals. The switch-board controlling this high-pressure current is of the most modern type, all the switches being operated by motors.

The three-phase generators are coupled direct to Curtis steam-turbines; this type of turbine is notable for the small floor-space occupied, the shaft being vertical. There are, at present installed, three turbines of 2,700 horsepower each.

The boiler-equipment consists of Babcock-and-Wilcox land-type boilers. The coal is elevated by an endless conveyor to overhead bunkers.

The auxiliary machinery is driven by electric motors: the current being obtained from dynamos driven by three high-speed Allen engines.

THE NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD AT THE NORTH STAFFORD HOTEL, STOKE-UPON-TRENT, JULY 10TH, 1905.

MR. JOHN NEWTON, VICE-PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

Mr. B. WOODWORTH read the following paper on a "Proposed Plant for Winding 250 Tons of Coal per Hour from a Depth of 3,000 Feet":—

PROPOSED PLANT FOR WINDING 250 TONS OF COAL PER HOUR FROM A DEPTH OF 3,000 FEET.

BY B. WOODWORTH.

To draw the coals alone up the shaft in tipping-boxes, instead of raising the coals and tubs containing them in ordinary cages, would enable the winding-engine to lift a paying load of 25 to 40 per cent. greater weight, without any increase of the total load. This would be a great advantage; but an important trouble would arise, namely, the dust created by tipping the coals at the pit-bottom from the tubs into the tipping-boxes for conveying them up the shaft. The writer sees no other difficulty which cannot be practically dealt with; and probably, to meet the dust-question, it would be necessary to use the upcast shaft as the drawing shaft for this special system of winding.

On the ordinary system it is proposed to carry an average paying load of 6¼ tons, with the cages running up to a maximum speed of 65 feet per second, and delivering 40 runs per hour; and to deal with this on the special system, the writer would use a paying load of 8 tons with the carrying-boxes running up to a maximum speed of 50 feet per second (for the same work done) and delivering 32 runs per hour.

The balance-rope working in both cases would be on the modified system previously described by the writer*, with an over-balance of 45 hundredweights to accelerate the starting and to retard the completion of the run, so as to avoid waste of power by braking or reversing the action of the engine, as far as possible. The winding-ropes and cages of the ordinary system would be placed in the downcast shaft and the balance-ropes in the upcast shaft, and they would run in accordance with the outline-plan and elevation (Figs. 1 and 2, Plate I.).

If tipping-box carriers were adopted and used in the upcast shaft as before stated, the balance-ropes would run down the back and front of the same shaft, in a line between the centre of the carriers; as the downcast shaft would be left free and used with an auxiliary plant for raising and lowering men, timber and other things necessary for the working of the mine.

The winding-engine would be of the horizontal compound and condensing double-tandem type, fitted with the accumulative injection-arrangement previously described by the writer,† using the progressive cut-off gear to the high-pressure cylinders, and bringing it into action as early as possible after the start of the winding. Further, as a provision for any emergency-working, an arrangement would be provided for working the four cylinders, independently of each other, with high-pressure steam, giving the low-pressure cylinders a fixed proportion of the maximum pressure used, and making the engine throughout sufficiently strong to stand the strains of such emergency-work when it was required. The length of run, proposed to be adopted, would be 36 revolutions per lift; and, to simplify the calculations, the rope-lap is taken as 84 feet per circumference, and the depth of shaft at 3,024 feet, thus practically avoiding the necessity for using decimals. The engine would have high-pressure cylinders 44 inches in diameter and low-pressure cylinders 66 inches in diameter, with a length of stroke of 7 feet. The boilers would be constructed to supply steam at a pressure of 150 pounds per square inch; and the winding-engine would be able to do the work freely, with a margin of 25 per cent. of reduction of the pressure.

* *Trans. North Staffs. Inst.*, 1891, vol. xi., page 80.

† *Trans. Inst. M. E.*, 1903, vol. xxv., page 156.

The winding-ropes, *a*, would weigh about 7·4 pounds per foot, and there would be, say, 10 tons hanging in the shaft; and the upper balance-rope, *b*, 3½ pounds per foot: both being of the highest quality of plough-steel wire of, say, 120 to 125 tons per square inch tensile strain (Fig. 2, Plate I.). To produce the over-balance of 45 hundredweights, named above, the lower balance-rope, *c*, would weigh about 12·4 pounds per foot, and be made either of a flat or round section, as considered most desirable; but, with the round-rope type, a turn-pulley at the bottom would be absolutely necessary. Small travelling cages, *d*, might be placed in the separate shaft, at the connections of the upper and lower balance-ropes, and used for examining the shaft, when required.

It is estimated that the weights of the four-decked cages and connections will be 6¼ tons each; eight or twelve tubs, 2¼ tons; and the coals, 6¼ tons. The average equivalent mass of matter in motion at full speed may be taken at 150 tons. The engine would run in full gear or 85 per cent. of admission of steam for the first two revolutions; the next twenty-two revolutions with a cut-off in the high-pressure cylinders, gradually reducing from about 55 to 40 per cent. of the full stroke for steam-admission; leaving the last twelve revolutions to be run without steam, and securing as much natural retardation as possible from the load and over-balance combined, so as to have a minimum waste of energy from brake-power or reversing the engine.

Table I. records the approximate actual results obtained with such working, shewing ample time for landing and onsetting, either simultaneously or by the two-stage system, and Fig. 8 (Plate I.) shews the approximate speed-curve for the winding.

Figs. 1 and 2 (Plate I.) shew the general arrangement of the drum and gearing proposed to be used. Figs. 3, 4 and 6 (Plate I.) illustrate the proposed method of construction of the drum. The drum-barrel for the rope-laps would be slightly conical, say, from 26 feet 5½ inches to 26 feet 7½ inches in diameter in the rope-grooves, and there would be space for spare or dead laps on each outside, with a spiral shoulder-rib, *a*, to lead the rope into its proper spiral form regularly round the drum, so as to match the successive grooves. The grooved plates would be of mild steel, rolled in suitable lengths, and six or eight grooves in width, to suit the rope used, and of such a pitch as

Fig. 5 (Plate I.) shews the type of construction of the drum which it is proposed to use, where the balance-ropes and the winding-ropes are placed in one shaft; this arrangement may be necessary in some cases, with the ordinary winding, and would probably be used in all cases where the special tipping-boxes were in use.

TABLE II.—SPECIAL SYSTEM OF WINDING COALS ONLY IN TIPPING-BOXES: THE AVERAGE EQUIVALENT WEIGHT IN MOTION, AT FULL SPEED, BEING 150 TONS, AS BEFORE.

No of Revolutions.	Admission of Steam.	Speed per Second.	Energy of Acceleration.	Work in lifting the Load.	Net Total of Power.	Time of Running.
		Feet.	Foot-tons.	Foot tons.	Foot-tons.	Seconds.
1 & 2	full gear	34	2,700	987	3,687	10·00
3 ,, 4	,,	48	2,250	1,029	3,279	4·00
5	,,	50	750	525	1,275	1·75
6	cut off	50	slight	546	546	
7 & 8	,,	50	,,	1,113	1,113	
9 ,, 10	,,	50	,,	1,155	1,155	
11 ,, 12	,,	50	,,	1,197	1,197	
13 ,, 14	,,	50	,,	1,239	1,239	
15 ,, 16	,,	50	,,	1,281	1,281	
17 ,, 18	,,	50	nil	1,323	1,323	
19 ,, 20	,,	50	,,	1,365	1,365	42·00
21 ,, 22	,,	50	,,	1,407	1,407	
23 ,, 24	,,	50	slightly retarding	1,449	1,449	
25 ,, 26	,,	50	,,	1,491	1,491	
27 ,, 28	,,	50	,,	1,533	1,533	
29 ,, 30	,,	50	,,	1,575	1,575	
		Steam shut off and retardation begins.				
			Engine-resistance.	Load-resistance.	Total natural retardation.	
31 ,, 32	shut off	41	168	1,617	1,785	3·75
33 ,, 34	,,	30	168	1,659	1,827	4·75
35 ,, 36	,,	9 to 10	168	1,701	1,869	8·50
Total ordinary resistance ...			... ...	... ...	5,481	
Balance of braking, etc. ...			... ...	... ...	219	1·25
Total, 38 foot-tons of energy on 150 tons				... ...	5,700	76·00

NOTE.—The total running-time is 76 seconds, and the landing-time, 36¼ seconds. The average paying-load is 8 tons. The maximum speed of winding is 50 feet per second, and 32 runs are made, on an average, per hour. The table contains the approximate results of working: the first to the fifth revolutions being made in full gear, and the rest with a fixed cut-off.

In the serious case of an accidental breaking of the winding-rope with an ascending load, *e*, even if it were near the surface, the descending cage, *f*, would have the resistance of the ascending heavy balance-rope, *c*, to assist in controlling its descent; and the engineman would, at the finish, only have to contend

with the weight of the descending cage, as the empty tubs and the winding-rope would be fully balanced by the weight of the bottom balance-rope (Fig. 2, Plate I.).

Table II. records the work done, if the special system of winding in tipping-boxes were in use, with a paying load of 8 tons, running at a maximum speed of 50 feet per second, so as to deal with the same output as before. The speed-curve diagram (Fig. 9, Plate I.) for this work shews how favourable the development of the engine-power would become under such conditions of working.

The use of tapered winding-ropes for such depths would make some appreciable reduction of weight without reducing the proportionate margin of safety in working; but the question arises whether the saving would be worth the variation, as the alteration of power required during the winding is found, from calculation, to be extremely small; and it would not be practicable to use special grooved plates with these ropes, owing to the variations of the diameter in the different portions of the same.

With this system in use, if it were found necessary to increase the output by, say, 25 to 40 per cent., it would be easy to wind up to a speed of 60 or 65 feet per second, without any alteration of the machinery beyond altering the cut-off gear to a longer range, so as to give the extra power required in the new circumstances. The only additional cost would be the reduced efficiency or increased volume of the steam used in the engines, and some additional waste of energy by the extra brake-power required in that case.

Mr. John Gregory said that the members were indebted to Mr. Woodworth for his valuable paper. The winding of coal from a depth of 3,000 feet was a problem that some of them would have to tackle, and it was a matter of regret that Mr. Woodworth had not elaborated the alternative scheme of using tipping-boxes. A similar arrangement was used at gold-mine plants, but, so far as he was aware, it had not been applied at collieries. Mr. Woodworth suggested that the coal, as it came to the bottom of the shaft, should be tipped from the pit-tubs either into a hopper or direct into tipping-boxes. It would then be taken up the shaft, and automatically tipped down shoots at the surface.

The mechanical idea seemed a good one, but there were many practical matters to be considered. Unfortunately, coal worked from a depth of 3,000 feet required careful handling: coal, at that depth, was much more tender; and, as it was, too much slack was made. The tipping coal into a box underground, and then again tipping it at the surface would militate, on this account, against the commercial success of any such system.

He (Mr. Gregory) did not agree with Mr. Woodworth when he advocated the use of a winding-rope having a tensile strain of 120 or 125 tons per square inch; he thought that strain was a little too high, although such ropes could be obtained; and most wire-makers advised that the strain should not exceed 110 tons.

He did not clearly understand Mr. Woodworth when he referred to the spare laps on the drum: it was usual to provide spare laps on the drum, but without using the dividing-flange shewn in Fig. 4 (Plate I.). Perhaps, Mr. Woodworth would further explain his ideas with regard to the use of the flange.

He thought that the special arrangement of the balance-rope was an excellent suggestion, as it would remove the weight of the balance-rope from the main capping. The capping of winding-ropes was one of the problems that had to be dealt with in deep mining. The weight of the winding-rope was enormous, and demanded some practical method of balancing it; Mr. Woodworth was well within the mark when he fixed the weight at 10 tons, and the weight of the balance-rope, as ordinarily used, was a serious additional load upon the capping of the rope. Mr. Woodworth avoided this additional strain by providing an auxiliary winding-rope, *b*, to carry the balance-rope, *c* (Fig. 2, Plate I.). The arrangement, however, necessitated the use of a heavier balance-rope, as the unbalanced weight of the main winding-rope required to be counterbalanced together with the weight of the auxiliary rope. This disadvantage, however, would be outweighed by the increased safety resulting from the removal of the load from the capping of the main rope.

He (Mr. Gregory) could hardly say whether the proposal to place two coils of the auxiliary rope round the drum and to use a C pulley would be a good one, but he feared that there would be a grinding action on the rope, and that the wear would be considerable.

He (Mr. Gregory) considered that the paper was an interesting one, particularly from the point of view of the balancing of the rope, rather than from the suggested adoption of tipping-boxes.

Mr. W. N. Atkinson agreed with Mr. Gregory that the breakage of coal produced by tipping it into boxes, in some cases, would be sufficient to prevent their use; and the dust-question, to which Mr. Woodworth had alluded, might be rather a serious matter in dry and dusty mines.

Mr. F. H. Wynne remarked that there was another point which would have a bearing on the use of tipping-boxes, and that was the working of a number of seams, sometimes eight or nine, drawn from one shaft, especially where the coals were, generally, used for three or four different purposes. It would be necessary that these coals should be kept separate in the tipping-boxes.

Mr. George E. Lawton observed that it would be a difficult matter to adopt tipping-boxes under the conditions mentioned by Mr. Wynne. Mr. Woodworth did not suggest that hoppers or bins should be used for the storage of the coal at the bottom of the shaft; it would be awkward and inconvenient to tip the coal direct from the tubs into the tipping-boxes, as it would necessitate the keeping of the tipping-boxes too long at the shaft-bottom. The breakage of the coal and the dust-question were important points. Mr. H. Johnson, of Dudley, had taken out a patent for a tipping-box arrangement; and he asked Mr. Woodworth to give his opinion with regard to that arrangement.

Mr. B. Woodworth observed that the tipping-box scheme was only suggested as an alternative. By properly considered arrangements, the loading and tipping of coal by tipping-boxes could be effected without increase of breakage over the ordinary-tub system. He would not have any hesitation in using ropes of 120 to 125 tons per square inch tensile strain; but he should not allow the engineman to deal with the slack rope in any deep system of winding. This would afford an increased factor of safety, as the manipulation of the slack rope by the engineman caused great jerks, and damaged the ropes.

In order to attain the proposed over-balance on the ordinary system of winding with a balance-rope under the cages, about 2

tons more must be added to each winding-rope, which was within 20 hundredweights of the weight of the top balance-rope. The total difference would then vary from 60 to 70 hundredweights.

The relative weights of the ropes in use under the ordinary and the modified system of winding, as described in his paper, were as follows:—

I.—ORDINARY SYSTEM OF WINDING.

	Tons.	Tons.
(*a*) Winding-ropes:		
Two ropes at 12 tons each	24	
Spare ropes to drum ...	2½	
		26½
(*b*) Balance-rope under the cages:		
One rope	12	
Over-balance	2¼	
		14¼
Total ...		40¾

II.—MODIFIED SYSTEM OF WINDING.

	Tons.	Tons.
(*a*) Winding-ropes:		
Two ropes at 10 tons each	20	
Spare ropes to drum ...	2½	
		22½
(*b*) Upper balance-rope:—		
One rope	4½	
Spare rope to drum ...	½	
		5
(*c*) Lower balance-rope:		
One rope	14½	
Over-balance	2¼	
		16¾
Total ...		44¼

The suggested grinding of the top balance-rope could only be ascertained by actual practice, but he did not think that it would prove as serious as was anticipated. He had used a winding-rope turned 2½ times round a wheel, 5 feet in diameter, at a small temporary plant for developing a colliery, and it had worked for two or three years satisfactorily.

Where different kinds of coal were worked, tipping-boxes with subdivisions could be used, so that each particular kind could be tipped where desired.

He did not think that Mr. Johnson's scheme was a practicable one, and a simpler method might be adopted to prevent the breakage of coal.

It had been stated recently that, in Lancashire, a winding speed of 80 miles per hour had been attained, but he believed that 50 miles per hour was rarely exceeded. At a speed of 80 miles per hour the energy in the moving bodies would exceed 200 foot-tons, and that was considerably higher than anything used in high-speed rope-driving at continuous work in cotton-mills.

The winding-drum was 17½ feet wide on the outside and 15 feet wide on the barrel. The lap of the rope was equally divided on each side of the centre-line of the pulley, and did not exceed 3 feet 3 inches in either direction. The rope would not

grind on the sides of the pulley, and the groove-pitch prevented side-grinding of the rope on the drum.

Mr. W. N. ATKINSON said that the question of winding from great depths was very important, and many difficulties of different sorts occurred in most cases of deep winding. He moved a vote of thanks to Mr. Woodworth for his valuable paper, and suggested that the discussion be adjourned.

Mr. JOHN NEWTON seconded the resolution, which was carried.

THE NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS AND THE SOUTH STAFFORDSHIRE AND WARWICKSHIRE INSTITUTE OF MINING ENGINEERS.

EXCURSION MEETING,
HELD ON JULY 24TH, 1905.

THE SOUTH STAFFORDSHIRE MOND GAS (POWER AND HEATING) COMPANY: DUDLEY PORT.

The South Staffordshire Mond Gas (Power and Heating) Company was formed by a special Act of Parliament in 1901, to make and distribute gas for power and heating purposes over the area extending from the city of Birmingham boundary to the borough of Wolverhampton on the one hand, and from Pelsall to Stourbridge on the other: an area of about 123 square miles, having a population of about 700,000 persons and comprizing the boroughs of Dudley, Smethwick, Walsall, Wednesbury, West Bromwich and Wolverhampton; the townships of Amblecote, Bilston, Brierley Hill, Coseley, Darlaston, Heath Town, Lye and Wollescote, Oldbury, Quarry Bank, Rowley Regis, Sedgley, Short Heath, Stourbridge, Tipton, Wednesfield and Willenhall; and the districts of Halesowen, Kingswinford and Walsall (including Bentley).

The first section of the works at Dudley Port, Tipton, comprizes eight producers, each capable of gasifying 20 tons of fuel per day of 24 hours, and generating sufficient gas to drive gas-engines of 2,000 horsepower continuously or about 16,000 horsepower in all. The slack coal is brought by boat into the canal-basin. The slack is unloaded by hand into bunkers, a little above water-level. From these bunkers, the slack is automatically fed into two conveyors, each having a capacity of 40 tons per hour, which distribute the fuel into the storage-bunkers over each set of producers. The bunker over each producer will hold 40 tons. The conveyors are driven electrically, by motors of about 5 horsepower.

The gas after leaving the producers, at about 450° Cent., is washed in mechanical washers, and after passing through the ammonia-recovery and gas-cooling towers, is further purified by large centrifugal fans, each of 45 horsepower, two of which are running in series at 850 revolutions per minute. The gas is then passed through scrubbers, before being compressed and sent through the mains for distribution.

The air-blast for working the producers is produced by three Roots blowers, each of 35 horsepower. The water-pumps can each pump 160 tons of water per hour. All the fans, washers, etc., are electrically operated, the electricity being generated by two three-cylinder vertical gas-engines, each of 250 horsepower, at 220 volts. Only one of these engines is running at a time, the other being kept as a standby. Three compressors, each of 450 horsepower, are used for forcing the gas through the mains, and each will compress 500,000 cubic feet of gas per hour.

Steam is provided by four Climax boilers, each of 500 horsepower, and evaporating 1,500 gallons of water per hour at a working pressure of 160 pounds per square inch.

Sulphate of ammonia is recovered by evaporation in stills, the crystallized sulphate being afterwards dried in a hydro-extractor.

The gas is measured by being passed through rotary meters, each capable of passing 500,000 cubic feet per hour.

Mains varying in size from 36 inches in diameter at the works to 21 inches at the end of the circuitor, have been laid, and are filled with gas through Toll End to Ocker Hill, where the main bifurcates, one leg passing through Bilston and into Wolverhampton, the other leg passing through Leabrook and Wednesbury into Walsall. Gas is, at present, being distributed under a pressure of 5 pounds per square inch. This pressure is reduced on the consumers' premises, by means of reducing valves, to the pressure suitable for each individual case. The total length of the trunk-mains laid, of the Ferguson locking-bar type, is about 13 miles.

The President (Prof. R. A. S. Redmayne) moved a vote of thanks to the officials of the South Staffordshire Mond Gas

(Power and Heating) Company for their courtesy in shewing the members round their works.

Mr. A. Smith seconded the resolution, which was cordially approved.

BIRMINGHAM UNIVERSITY.

The plan has been so designed as to allow of allocating a separate block of buildings to distinct subjects, namely, mechanical engineering, with a hall of machines; and civil, electrical and mining and metallurgical engineering; and an arts department. The architect's design provides three further blocks to be devoted to subjects not provided for in the present buildings. There is a central hall, common to all the departments. The plan is semi-circular, the blocks radiating from the central hall and being connected together by a large semi-circular corridor, in the basement of which will be placed the heating apparatus, warming the ventilating current as it passes to the different blocks.

The outbuildings and works comprize the experimental mine, covering over ¾ acre, constructed on one-third scale. The mine will be put to the practical uses of instruction in underground surveying and levelling, connecting surface and underground surveys, and demonstrating the different systems of mine-ventilation. The various systems of timbering and haulage will also be demonstrated.

The equipment of the power-station is of a most varied character, containing, as it does, power-generators of almost every type. The plant is designed to supply power to the machines and plants of the various departments, for heating and for ventilation, etc., and also to serve as an example of the practical application under working conditions. The boiler-house is fitted with boilers of modern type, capable of supplying 1,000 horsepower; and a Mond gas-plant, of 250 horsepower, supplies gas to the large gas-engines, etc.

The steel-foundry comprizes a Siemens steel-furnace, of 2 tons capacity, with crane, ladle, ingot-pit, electric hoist, etc. The iron-foundry has a cupola, sand-beds, casting-boxes, etc. The brass-foundry has pot-furnaces, moulding-benches, frames, etc.

THE NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD AT THE NORTH STAFFORD HOTEL, STOKE-UPON-TRENT, SEPTEMBER 11TH, 1905.

MR. E. B. WAIN IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen, having been previously nominated, were elected:—

MEMBERS—

Mr. THOMAS DOBSON, Silverdale Collieries.
Mr. A HALL, The College, St. John, Barbados, British West Indies.
Mr. HARRY MITCHESON, Florence Colliery.
Mr. W. G. SALT, Norton Colliery, Ford Green.
Mr. THOMAS YATES, Brynkinalt Colliery, Chirk.

ASSOCIATE—

Mr. V. F. WITHEY, Florence Colliery.

STUDENT—

Mr. WILFRID WOOTON, 82, Park Road, Fenton.

Mr. W. G. PEASEGOOD read the following paper on "A Gob-fire in the Ten-feet Seam, North Staffordshire":—

A GOB-FIRE IN THE TEN-FEET SEAM, NORTH STAFFORDSHIRE.

By W. G. PEASEGOOD.

The writer thinks it advisable to record a case of gob-stink, which occurred in the Ten-feet seam of the Fair Lady pit, Leycett collieries, inasmuch as this seam had never before been known to fire.

The ordinary section of the Ten-feet seam is as follows:—

	Ft.	Ins.
Ten-feet rock	15	0
Soft shale	0	5
Metals	1	10
Rock-bind	1	0
Dark-grey bass	4	4
Soft shale	0	4½
Dark-grey bass	7	6

	Ft.	Ins.	Ft.	Ins.
Ten-feet Coal-seam—				
COAL, Tops ...	2	6		
COAL, Main ...	5	6		
Stone-parting ...	0	1		
COAL, Stools ...	1	0		
	——		9	1
Light-grey shale			1	0
Clunch			7	5
Rock and rock-binds			12	0

The depth from the surface to the seam, where the stink was perceived is about 1,635 feet.

The district (Fig. 1, Plate II.) was headed out in December, 1903, the main level being stopped at an upthrow-fault, and rise-places were driven to the south-east. Drifting was then commenced, and continued until the beginning of March, 1905; it was then getting in advance of the workings to the north-west, and it was, consequently, stopped for the time being. The seam and the goaves give off gas very freely, and the top part of the goaf was naturally charged with gas. The district stood for three months, and then work was resumed in order for drifting back again. This was started on Friday, May 26th, and on the following Monday, May 29th, at 7·30 a.m., a strong gob-stink was found.

All the rails, etc., were taken up and out to the point, A, on the plan (Fig. 1, Plate II.), where it was intended to bring down the gas, in order to charge the goaf; and by 3 p.m., the ventilation had been so cut off and short-circuited that the goaf, where the stink was perceived (marked B on Figs. 1 and 2),

was charged with gas. The stink, mixed with gas, came down to the bottom of the jig-dip, C, on to the main level, by 4·30 p.m. From this point, all trace of the stink was lost, although the gas came along the level and down the dips to the point, A, by 7·30 p.m., a difference in height of 63 feet to where the stink was found.

The ordinary floor of the Ten-feet seam is a strong light-grey shale, but when the change of dip took place at B (Figs. 1 and 2, Plate II.), this shale became of a softer nature, from 9 to 12 inches in thickness underneath the coal.

Owing to the very heavy dip, large slips of coal occurred, and the colliers were in one instance loading coal for 6 months off the same pair of rails. When these slips occurred, a portion of the soft floor came with the coal, rendering it very difficult to get clean coal; and, in consequence, a certain amount of coal, rather more than usual, was left in the goaf. Very little of the roof-bass, and none of the rock, which lies above the seam, was seen, as is usual in heavy falls.

In the writer's opinion, this fire was caused primarily by the heavy grinding which took place on the mixture of dirt and coal, and thereafter, the taking away of the gas on the goaf-edge in order to resume work gave sufficient air to start the actual fire.

Luckily, the position and inclination of the workings were favourable to the district being quickly charged with gas, and the management will, in future, have to resort to working this seam on the panel-system, so as to guard against possible fires.

Mr. A. M. Henshaw asked whether this was the first gob-fire that had taken place in the Ten-feet seam of North Staffordshire. He should like to know whether the coal was naturally hard or soft, and what percentage of slack was produced. He should like to know whether any analyses had been made of the coal, or of the different bands in the seams, so as to see whether there was any particular propensity to spontaneous combustion in any part of the seam. It was the first time that he had come across a real gob-fire extinguished without the erection of stoppings. He would also like to know the character of the gob-stink: whether there was merely

a smell, or whether there was any further evidence of actual fire or vapour. He asked how long the district had been closed, and how long the particular part had been charged with gas; what was the condition of the goaf, and whether it was clean, or more or less full of broken coal and fallen roof. He should also like to know whether the seam was dry and dusty; what volume of air passed in and out of the district, and by which course and at what velocity; and whether there was any pressure upon the part of the goaf that fired.

Mr. J. C. Cadman remarked that he never knew of a gob-fire in the Ten-feet seam. The seam had been extensively worked, he had worked a large area of this seam at Silverdale and Apedale collieries, and had not been troubled with gob-fires. If, in working this seam at great depths, it became more liable to spontaneous combustion, it would be necessary to exercise greater care and to adopt the panel-system of working.

Mr. A. M. Henshaw thought that there must have been exceptional conditions in this case. There must have been a large accumulation of probably dust or slack, in the places at the bottom of the rearer coal where the gob-fire occurred.

Mr. John Cadman observed that there must have been enormous pressure on the contorted area in which the gob-fire took place, and it would considerably increase the surface exposed to oxidation. It would be interesting to know whether any seams had been worked contiguous to the Ten-feet seam.

Mr. A. Hassam said that, as one who was formerly connected with Leycett, he felt especially interested in Mr. Peasegood's paper. He was not altogether surprised when he heard that there was gob-stink in that portion of the mine. When that district was opened, it was decided, after discussion, to adopt a modification of the panel-system; so the first panel was worked out in that way, and barriers were left. He was surprised to hear that they had had a gob-fire at the Leycett collieries, and had been able to deal with it without putting in stoppings. He thought that it would have been prudent to have erected stoppings, as one never knew what was going to happen with gob-fires. He did not at all agree with the writer that the heating was due to grinding and crushing. He con-

sidered, after considerable experience in gob-fires, that the dominating factor was chemical and not mechanical. He believed that the greater depth and consequent higher temperature, and greater dryness facilitated gob-heating. The Ten-feet seam, so far as he knew, had never fired before, and at this point it was deeper than at any place on the western side of the coal-field. This fire had demonstrated a new source of danger in this seam, and at these greater depths the system of work to be adopted would have to be very carefully considered.

Mr. T. E. Storey stated that he had worked the Ten-feet seam at Leycett and other collieries in the district, but had never, before, heard of a gob-fire in that seam. He agreed that the fire, to some extent, was probably owing to the great depth of the working and the consequent increase of pressure upon the coal. He considered it very unusual to extinguish a gob-fire without putting in stoppings.

The Chairman (Mr. E. B. Wain) thought that Mr. Peasegood had judged wisely in putting down this gob-fire to frictional causes. Although Mr. Hassam said that the action in gob-fires was more chemical than mechanical, it must not be forgotten that mechanical or frictional action produced heat, and that the heat, so produced, accelerated chemical action.

Mr. W. Statham moved a vote of thanks to Mr. Peasegood for his interesting paper.

Mr. F. H. Wynne, in seconding the resolution, remarked that it was with the object of hearing and discussing such papers as this that the Institute was founded, so that the mining community in general might benefit by the experiences of individuals; and that it was unfortunate that full records of similar occurrences were not communicated, more frequently, to the members.

The motion was cordially approved.

THE NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

ANNUAL GENERAL MEETING,

HELD AT THE NORTH STAFFORD HOTEL, STOKE-UPON-TRENT, OCTOBER 23RD, 1905.

MR. A. H. HEATH, M.P., PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen, having been previously nominated, were elected :—

ASSOCIATES—

MR. ALFRED EARDLEY COOKE, 14, Barracks Road, Newcastle-under-Lyme, Staffordshire.

MR. JOHN JAMES WADDELL, The Marabella Manjak-mine, San Fernando, Trinidad, British West Indies.

STUDENT—

MR EDGAR ADAMS, The Croft, Sneyd Green, Burslem.

The Annual Report of the Council was read as follows:—

ANNUAL REPORT OF THE COUNCIL, 1904-1905.

The Council have to report that the names of 17 gentlemen have been added to the list of members during the year. There have been 2 transfers and 6 resignations; and 49 names have been written off, owing to non-payment of subscriptions. The Council regret having had to strike off so many names, but it may be explained that many of these members have left the district or ceased their connection with mining.

The following table shows the membership during the past 10 years:—

Year ending.	Life Members.	Honorary Members.	Members.	Associate Members.	Associates.	Students.	Totals.
July 31st, 1896.	1	6	120	3	37	16	183
„ 1897.	1	6	116	5	36	19	183
„ 1898.	1	5	112	4	46	14	182
„ 1899.	1	5	106	5	43	13	173
„ 1900.	1	6	108	4	44	12	175
„ 1901.	0	6	130	9	53	22	220
„ 1902.	0	7	140	10	67	27	251
„ 1903.	0	7	145	11	73	26	262
„ 1904.	0	9	145	12	70	26	262
„ 1905.	0	9	128	9	51	26	223

During the year, general meetings were held in September, October, December, January, March, May and July, and excursion meetings in August and July.

The following papers were read during the year:—

"The Taxation of Collieries." By Mr. A. Hassam.
"Presidential Address." By Mr. A. H. Heath, M.P.
"The Transmission of Power by Ropes." A lecture by Mr. E. Kenyon.
"The Development of Higher Education in North Staffordshire." By Prof. Thomas Turner.
"An Electric Indicating Two-wire Signal." By Mr. J. Willis.
"Proposed Plant for Winding 250 Tons of Coal per Hour from a Depth of 3,000 Feet." By Mr. B. Woodworth.

With a view to induce members to read papers at general meetings during the current year, the Council have decided to offer prizes of the value of (*a*) £3 3s. and (*b*) £2 2s. for the best paper read at general meetings by: (*a*) Members and Associate Members, and (*b*) Associates and Students.

With reference to the County Council Mining Classes, last session was perhaps the most successful yet held in North Staffordshire. There was a satisfactory increase in the number of students, and about 96 took the County Council examination in May last. The prize-distribution took place on November 19th, 1904, when an eloquent address was delivered by Mr. W. Y. Craig, past-President of the Institute, and the occasion will long be remembered by those who were present.

During the first week in August, the County Education Committee sent five of the advanced students to the Lancashire coal-field, under the guidance of the lecturer (Mr. J. T. Stobbs), and representative collieries were visited. The party were very much indebted to the mining engineers of that coal-field for the

exceptionally kind way in which they were received at all the collieries.

The scheme for the establishment of a College of Science in North Staffordshire now seems to be on an assured basis, the County Council having resolved to accept the gift of the site from the executors of the late Mr. A. S. Bolton, and to build thereon a college for the purposes of higher education at a cost not exceeding £25,000; provided that £12,500 is raised by individuals or bodies other than the County Council, and is paid over to the County Treasurer or fully guaranteed. The sum already at the disposal of the Mining Institute for the building fund amounts to £1,634 10s., of which £1,221 is now in the bank. This is less than half the sum which the Council thinks should be contributed towards the establishment of the college by the important mining and allied industries of the district. A further appeal for funds will therefore be made, and with the practical assurance that the college will shortly be built, and with the improving outlook in trade, it is hoped that a sum worthy of the mining industry of the district will be available when required.

ANNUAL REPORT OF THE TREASURER, 1904-1905.

The TREASURER (Mr. Thomas Ashworth) submitted the following statement of the accounts for the year ending July 31st, 1905:—

The total receipts amounted to £365 13s. 1d., of which £280 3s. 6d. is for current-year subscriptions, and £56 4s. received for arrears. Of last year's arrears of £277 19s., there has been written off £151 16s., leaving £69 19s. to carry forward, after deducting the above sum of £56 4s. The present year's arrears are £82 2s., making altogether a total of £152 1s. of arrears outstanding.

The sale of *Fossil Charts* has yielded £2 3s. 2d., and the sale of *Transactions*, etc., £1 14s. 3d.

The sum of £7 9s. 4d. has been expended on library-account, and paid out of revenue.

The result of the year's working has been to increase the credit-balance from £101 0s. 7d. at the end of the previous year, to one of £147 8s. 9d. at the end of July, 1905.

DR. THE TREASURER IN ACCOUNT WITH THE NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS CR.
FOR THE YEAR ENDING JULY 31ST, 1905.

DR.	£ s. d.	£ s. d.	£ s. d.
August 1st, 1904.			
To Balance brought forward from last account			101 0 7
July 31st, 1905.			
To subscriptions for the year 1904-1905		291 19 6	
,, arrears received for year 1903-1904	30 13 6		
,, ,, ,, 1902-1903	8 17 6		
,, ,, ,, 1901-1902	4 14 0		
,, ,, ,, 1900-1901	3 8 0		
,, ,, ,, 1899-1900	5 3 0		
,, ,, ,, 1897-1898	3 8 0		
		56 4 0	
		348 3 6	
Less subscriptions for 1904-1905, received prior to August 1st, 1904		11 16 0	
			336 7 6
To sales of dinner tickets		10 7 8	
,, ,, Prussian Reports		5 2 0	
,, ,, *Fossil Charts*		2 3 2	
,, ,, *Transactions*		1 15 3	
,, ,, Excerpts		0 14 0	
			20 2 1
,, subscriptions for the year 1905-1906, received in advance			9 3 6
			£466 13 8

I have examined the foregoing account with the books and vouchers, and certify the same to be correct.

W. H. EARL,
CHARTERED ACCOUNTANT.

NEWCASTLE-UNDER-LYME, *August 31st*, 1905.

CR.	£ s. d.	£ s. d.	£ s. d.
July 31st, 1905.			
By the Institution of Mining Engineers:			
Calls for 1904-1905, 167 at 19s.	158 13 0		
,, 1903-1904, 6 at 19s.	5 14 0		
Supplying *Transactions* to members	1 0 0		
		165 7 0	
200 copies of Prussian Report	6 0 0		
Proportionate cost of exchanges	3 13 0		
		9 13 0	
			175 0 0
,, ationery			23 15 2
,, exhibition, etc.			21 2 5
,, Rent and hire of rooms			14 1 0
,, Storage of books			1 1 0
,, Secretary's salary and expenses ...		60 15 11	
,, Commission for collecting arrears ...		0 16 11	
,, Reporter's salary and expenses .		12 17 0	
,, Treasurer's postages, etc. ...		1 13 2	
,, Norwich Fire Insurance Premium		0 8 9	
			76 11 9
,, Library account			7 9 4
,, *Fossil Chart* account			0 4 3
,, Balance in the bank			147 8 9
			£466 13 8

DR. **THE TREASURER OF THE NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS IN ACCOUNT WITH SUBSCRIPTIONS FOR THE YEAR 1904-1905.** CR.

	£ s. d.	£ s. d.
To 137 Members and Associate Members at £2 2s.	287 14 0	
,, 9 Honorary Members		
146		
,, 51 Associates, less 1s. 6d. overpaid last year, at £1 6s.	66 4 6	
,, 26 Students at 15s. 6d.	20 3 0	
		374 1 6
223		
,, Subscriptions for the year 1905-1906, received this year	...	9 3 6
,, Arrears brought forward from 1904 ...	277 19 0	
Less arrears written off, and allowed by Council	151 16 0	
		126 3 0
		£509 8 0

	Paid. £ s. d.	Unpaid. £ s. d.
By 112 Members and Associate Members paid, at £2 2s.	235 4 0	......
,, 25 Members and Associate Members unpaid, at £2 2s.	......	52 10 0
,, 9 Honorary Members	......	......
146		
,, 33 Associates, less 1s. 6d. overpaid last year, paid, at £1 6s. ...	42 16 6	......
,, 18 Associates, unpaid, at £1 6s. ...	......	23 8 0
51		
,, 18 Students, paid at 15s. 6d. ...	13 19 0	......
,, 8 do. unpaid, at 15s. 6d. ...	.....	6 4 0
26	291 19 6	82 2 0
223		
,, Subscriptions for the year 1905-1906, received this year £9 3 6		
,, Arrears received this year 56 4 0		
	65 7 6	......
,, Arrears outstanding on July 31st, 1905	......	69 19 0
	357 7 0	152 1 0
		357 7 0
		£509 8 0

ANNUAL REPORT OF THE LIBRARIAN, 1904-1905.

The LIBRARIAN (Mr. F. H. Wynne) submitted the following report for the year ending July 31st, 1905:—

During the year, 37 volumes have been bound and added to the already valuable and comprehensive collection of literature which is available to the members of this Institute. The storage-capacity, too, has been increased, by the addition of a further set of book-shelves.

Mr. W. N. ATKINSON moved the adoption of the reports.

Mr. E. B. WAIN seconded the resolution.

The PRESIDENT (Mr. A. H. Heath) said that the reports seemed to be perfectly satisfactory, and the Institute appeared to be in a flourishing condition in every way.

The reports were adopted.

ELECTION OF OFFICERS, 1905-1906.

The following officers were appointed:—

PRESIDENT:

Mr. A. H. HEATH, M.P.

VICE-PRESIDENTS:

Mr. G. P. HYSLOP.	Mr. G. A. MITCHESON.	Mr. JOHN NEWTON.

TREASURER:

Mr. THOMAS ASHWORTH.

SECRETARY:

Mr. F. R. ATKINSON.

COUNCILLORS:

Mr. F. E. BUCKLEY.	Mr. G. E. LAWTON.	Mr. W. STATHAM.
Mr. J. GREGORY.	Mr. W. LOCKETT.	Mr. J. T. STOBBS.
Mr. A. HASSAM.	Mr. W. G. PEASEGOOD.	Mr. W. TELLWRIGHT.
Mr. J. HEATH.	Mr. T. ROBERTS.	Mr. F. H. WYNNE.

The PRESIDENT (Mr. A. H. Heath) delivered the following address:—

PRESIDENTIAL ADDRESS.

By A. H. HEATH, M.P.

The PRESIDENT expressed his thanks to the members for having re-elected him. He regretted that he had not been able to attend their meetings so frequently as he ought to have done during the past year.

Be that as it might, he thought that their object in re-electing him was, as last year, to help them to promote, as far as he could, the scheme for the erection of a College in North Staffordshire. If that were their reason, he assured them that he was all the better pleased to preside over their councils again, in the hope that something more definite might result than had been the case during the past twelve months.

The annual report just read seemed to him to be in every way satisfactory. It was true that there was a falling off in membership from 262 in 1904 to 223 in 1905. But this was entirely owing to the fact that many purely ornamental names had been removed from the list, the owners of which neither honoured the Institute with their company nor contributed anything to the finances in the way of subscriptions. This accounted for the diminution in the number of members. In other respects the report seemed, as he had said, to be thoroughly satisfactory.

With regard to the lack of enterprise on the part of members in coming forward with papers, and to the prizes offered by the Council to encourage them, he said he should be glad to place at the disposal of the Council a similar sum to the first prize offered by the Council, for any like object that they might deem it desirable to support. He was sure that the youngest member would be very warmly received, and the greatest measure of encouragement would be given to him if he would only make an attempt to read a paper to the Institute on any subject that he liked to select. The scope was as wide as it could possibly be, and there was no subject affecting either the local industries or

the mining and mechanical engineering trades which did not offer great facilities for the students of the Institute to display their abilities.

The President observed that he hardly knew what to say to them on the subject of their work. He knew of nothing that had taken place during the past twelve months which was of peculiar interest to themselves. They had been paddling along in the usual way, doing the best they could in their different industries, and he felt that without the scientific skill and ability of the members of their profession they would be in a very much worse plight than they were now.

When he thought of the almost total dependence upon engineering of industries like the coal and iron trades, he could not help thinking it was a great pity that the employers in this district did not do something far more practical to give the fullest encouragement to their profession. He often thought that something might be done to facilitate experiments in designs and inventions, which many engineers were too loth to bring forward, because they thought there was no reasonable prospect of their being carried into effect. This was a difficulty he was sure that they must feel, because very often for lack of means to further any invention they let it fall to the ground. Combination amongst the employers for the purpose, through the Mining Institute, might be of great service. There were possibilities, he thought, in connection with the proposal for a mining school, of promoting facilities of this sort in mining engineering. Everything which tended to cheapen production was what they desired, and he could imagine nothing more likely to promote the local industries than improved mechanical appliances. He believed that they had made as great advances in that district as had been made in any other. They saw new works, improved machinery, and better appliances in every direction, and he did not think that North Staffordshire was the least bit behind any other district in Great Britain in the matter of mechanical invention and application.

The inspector of mines (Mr. W. N. Atkinson), who took a very deep interest in anything which was responsible for the safety of the mines of the district, would tell them, he thought, that they did everything they could to ensure the safety of the mines; but in a district where coal was more difficult to

get economically and safely, owing to the gradients of the mines, than in any other district in Great Britain, there was the fullest scope for genius to come forward and assist.

He believed that he was re-elected President of the Institute more with a view to promote the interest of the Mining College, than anything else, and he wanted to mention it particularly that day, because he believed that they had arrived at a turn in the course when they had to decide definitely whether they were to have the College or not. In the *Report* it was pointed out that the County Council were willing to provide very liberally towards the scheme, but only on condition that the balance necessary for carrying out the scheme in its fulness was supplied in the district. They owed a great debt of gratitude to the late Mr. A. S. Bolton and his successors for having given the site. The County Council must have felt that the site which was offered was the best one for a training college that the district could furnish. Personally, he (Mr. Heath) could not imagine a better one for the purpose; and he thought that they would be very false indeed to their traditions if they did not take advantage of the opportunity so generously provided for them. It was, of course, quite possible to build a mining school without any such adjuncts as a training college and a pottery school, but he did not think that any school they could establish could be so satisfactory as one which was identified with a great institution provided for the purpose of higher education generally. The general scheme had been approved by the County Council, and they were quite willing to do their share in promoting it by finding £12,500, about half the sum required for the building, if the district did the rest. Last year he said that he had every confidence that the colliery-owners of the district would support the scheme, and the best guarantee of their interest was that they had already contributed about half the amount which they would be required to find for the Mining College. So far as that school was concerned, therefore, he thought he could say that the money was really acquired. Of the pottery school he could say nothing. He believed that there had been some kind of a promise to find the amount necessary to support the school. He hoped that the potters would realize how important it was to give every facility for the higher training of their employees, and those who were going to be their employees, in the future. He hoped that they

would look at it in much the same light as the mining people in the district had looked at their school. But there would still be a further balance of some £3,000 to be found after the mining and pottery schools had been provided. The question now was: where were they to get this sum? He did hope that before long the matter would be taken up in earnest, and that the President of the Council for the Extension of Higher Education in North Staffordshire would shortly call a meeting of representative people in the district at which subscriptions might be invited, and also that a really active committee of practical men identified with the district would be appointed to raise the small amount which would be necessary to ensure the grant from the County Council. The County Council had to find a college (he believed in the year after next) for the training of teachers, and if that district did not encourage them by finding the other portion of the money to erect the school at Stoke, it was quite likely that they would set it up somewhere else, and consequently that district would be the loser. He trusted, therefore, that the committee would be formed, and he hoped that practical steps would be taken to raise the balance. He hoped that during the ensuing year the Council for the Extension of Higher Education in North Staffordshire would be able to give them some definite idea as to when the foundation-stone of the college was to be laid.

Mr. W. N. Atkinson proposed a hearty vote of thanks to Mr. Heath for his address. He observed that every member felt that in Mr. Heath they had the best President that they could possibly get, especially under present conditions. With regard to the college-scheme, he (Mr. Atkinson) felt that it had now arrived at a stage when it was bound to go on or fall through, and he thought that the latter eventuality was out of the question. The amount required to build the college was only £25,000. He did not think that they ought to limit themselves to the minimum necessary, but if possible they should try to make the sum larger. As to the actual educational sections of the college, the members were, of course, most interested in the mining and mechanical departments; but, to his mind, it seemed the most natural thing in the world that the two staple industries in the district (pottery, and mining and metallurgy) should be combined

in one institution. The section for the training of teachers must also be advantageous, as the college might then embrace the arts as well as the sciences.

Mr. J. Newton, in seconding the resolution, said that it seemed to have been overlooked that the college-scheme had not progressed as it might have done if times had been better. Unquestionably, during the last few years, trade in their district had been very poor, and many of the coal-owners and potters had had a struggle to exist.

The resolution was carried, and the President briefly replied.

THE PROPOSED SCIENCE COLLEGE FOR NORTH STAFFORDSHIRE.

Mr. W. N. Atkinson moved, and Mr. J. C. Cadman seconded the following resolution, which was carried unanimously:—

> The North Staffordshire Institute of Mining and Mechanical Engineers urge the Council for the Extension of Higher Education in North Staffordshire to call an early meeting, for the purpose of making arrangements for the collection of the balance required by the County Council for the erection of the college, seeing that a considerable part of the fund for building the mining school has already been provided.

There was, as usual, an interesting exhibition of mining appliances; and the meeting was followed by the annual dinner, over which Mr. A. H. Heath, M.P., presided.

THE MINING INSTITUTE OF SCOTLAND.

GENERAL MEETING,

HELD IN DOWELL'S ROOMS, EDINBURGH, AUGUST 19TH, 1905.

DR. ROBERT THOMAS MOORE, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen were elected:—

MEMBERS—

Mr. JOHN BOYD, Brema, Mount Vernon.
Mr. WILLIAM CALDWELL, Pumpherston Oil Company, Mid-Calder.
Mr. D. LANDALE FREW, 3, Melrose Street, Glasgow.
Mr. JAMES HAMILTON, Rosewell, Midlothian.
Mr. GEORGE F. MACKAY, 222, Broomielaw, Glasgow.
Mr. ARCHIBALD M'NEIL, Smithfield House, Bonnybridge.
Mr. DAVID RANKINE, Craigview, Uphall.
Mr. WILLIAM HOUSTON RODGER, Dreghorn.
Mr. JOHN WILSON, Shields Colliery, Motherwell.

ASSOCIATE MEMBERS—

Mr. ADAM HUNTER BAIRD, Annickbank, Cambuslang.
Mr. ERNEST KING, 54, Inveresk Road, Musselburgh.

ASSOCIATE—

Mr. JAMES M'CUBBREY, Milnwood Colliery, Bellshill.

DISCUSSION OF MR. ARCHIBALD RUSSELL'S PAPER ON "THE COAL-FIELDS OF CAPE COLONY."*

The PRESIDENT (Dr. R. T. Moore) said that a large area containing coal was found in Cape Colony. The seams, with one exception, appeared to be comparatively thin, and they were

* *Trans. Inst. M.E.*, 1905, vol. xxix., page 228.

all split up with bands of stone. The coal contained a high percentage of ash, and was somewhat inferior to Welsh coal. In Cape Colony there was always a local market, and it came to be a question whether the cheaper article of an inferior quality did not give as good results as the better but higher-priced Welsh coal. Mr. Russell said in his paper that the output of coal in Cape Colony had been steadily increasing; and this was due to the fact that the coal was used for markets for which a better quality of coal was not available.

The discussion was adjourned.

THE MINING INSTITUTE OF SCOTLAND.

GENERAL MEETING,

HELD IN THE ODDFELLOWS' HALL, KILMARNOCK, OCTOBER 14TH, 1905.

MR. JAMES HAMILTON, VICE-PRESIDENT, IN THE CHAIR.

The members visited the works of Messrs. Andrew Barclay, Sons & Company, Limited, Kilmarnock, and examined the Oddie-Barclay pump, working under a head of 700 feet.

A vote of thanks was accorded to the Company and to Mr. Thos. Turner, their representative.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen were elected:—

MEMBERS—

Mr. DUGALD BAIRD, Annickbank, Cambuslang.
Mr. JAMES BAULD, Drumley, Annbank.
Mr. JOSEPH CHAPMAN, Russell Street, Burnbank, Hamilton.
Mr. ROBERT CURRIE, Darnconner, Auchinleck.
Mr. GEORGE KNOX, Technical and Mining College, Wigan.
Mr. ROBERT G. M'CULLOCH, Carriden Colliery, Bo'ness.
Mr. JOHN PATTERSON, Trabboch, Coylton, Ayr.
Mr. ROBERT WALKER, Carriden Colliery, Bo'ness.

STUDENT—

Mr. JOHN F. K. BROWN, 152, Renfrew Street, Glasgow.

The CHAIRMAN (Mr. Hamilton) moved that a hearty vote of thanks be given to Mr. Archibald Russell for his paper on "The Coal-fields of Cape Colony."

The following paper on a "Hydraulic Pumping-installation at Loanhead Colliery, near Edinburgh," was read by Mr. Robert Crawford:—

HYDRAULIC PUMPING-INSTALLATION AT LOANHEAD COLLIERY, NEAR EDINBURGH.

By ROBERT CRAWFORD.

Loanhead colliery, of the Shotts Iron Company, Limited, is situated on the steep measures of the Midlothian coal-field. The mine in which the pumping arrangement to be described is installed is an inclined shaft, following the coal-seam from its outcrop to a depth of 1,620 feet on the slope or 1,200 feet perpendicular, the average gradient being 52 degrees. The water is pumped from the bottom of this inclined shaft, a distance of 660 feet perpendicular, to the Ramsay level, along which it flows for 4,200 feet to the Ramsay pit, where steam-pumps (which need not be here described) raise it a further height of 360 feet to an adit-level communicating with the river Esk.

The pumping-plant is worked upon the Brown and the Hathorn-Davey hydraulic systems respectively: the water being raised in one lift of 660 feet vertical to the Ramsay level.

No. 1 Power-engine.—The arrangement consists of a vertical compound power-engine placed on the surface, having high-pressure and low-pressure cylinders respectively 19 and 30 inches in diameter and 2 feet stroke. Steam is supplied at a boiler-pressure of 100 pounds per square inch, the cut-off taking place at 0·625 of the stroke in the high-pressure cylinder. The engine is placed close to the boilers, so that there is very little loss due to condensation between the boilers and the engine. The cranks are set at right angles, with double connecting rods, and on the crank-shaft are fitted three flywheels which keep the engine working with a uniform motion, and in addition maintain an equal strain across the crank-shaft. The average number of revolutions per minute is 56.

The power-pumps are two in number, and the pump-rods are attached directly to the piston-rods of the engine. The pumps are 5 inches in diameter and of the bucket-and-plunger

type, consisting of a U-shaped leather, fitted to the pump-rod by an arrangement of brass washers, and held against a collar on the rod by means of a locked nut. Primarily, there were two inverted leathers on each pump, fitted so as to butt against each other; but experience has shewn that, in cases where one side is under constant pressure, quite as satisfactory results can be obtained by dispensing with the bottom leather entirely, as it only adds unnecessary friction to the pump. These pumps supply a continuous feed of water into the power-main at a pressure of 850 pounds to the square inch, and generally run for 12 months without requiring to be changed. The pump barrels are made of cast-iron lined with gun-metal. The suction- and delivery-valves are made of bronze, and are of the conical type.

The power-water is conveyed by a pipe, 4 inches in diameter, to the hydraulic pumps in the mine, and is returned through an exhaust-pipe, 4½ inches in diameter, to a water-tank on the surface. The pipes are ⅜ inch thick: they are coupled in the manner usual with hydraulic piping, and tested, before being put to work, at a pressure of 2,000 pounds to the square inch, so that very little trouble is experienced after they are fixed in position. The suction-pipe of the power-pumps is connected to the water-tank, and consequently the same water is used over and over again. By this arrangement, clean water is used to avoid the excessive wear-and-tear of the power-pumps, and underground pump power-valves and motor-barrels, which would take place if they were worked with the gritty mine-water. Various lubricants have been tried, but ordinary soft soap has been found to give the most satisfactory results, 4 to 5 pounds being added to the water per shift.

In this system of pumping, nothing is required in the nature of an accumulator of power, as the work done is constant. All that is required is that a constant pressure of 850 pounds per square inch be maintained in the power-main, and that is secured, in this case, by the employment of a steam-regulator, consisting of a small throttle-valve fitted on the steam-pipe next to the high-pressure cylinder and attached by a spindle and a spring to a small ram in connection with the power-main. The strength of the spring is equal to the normal pressure, but as soon as the pressure in the power-main falls below the normal, as would happen when a pipe bursts or a joint gives way, the spring forces

the ram down and at the same time actuates the throttle-valve, thereby shutting off the steam from the engine. On the power-main, there is fitted a spring safety-valve which is set to the normal pressure, but as soon as the pressure rises above the normal, as would happen if the pump in the mine were suddenly stopped, the valve acts and prevents any mishaps, such as pipes bursting or joints failing.

The suction-pipe is 13 inches in diameter, and on it is fitted an air-vessel by means of which the water-pressure at the engine is kept practically constant, and in addition it acts as a cushion to the water when the suction-valve closes. There is also a small snifter air-valve fitted on the suction-pipe admitting a certain quantity of air at every stroke of the pump so as to aerate the power-water and thereby avoid knock in the power-main. The *modus operandi* may be thus described: During the upstroke of the pump, water is drawn from the tank; at the same time there is drawn in, through the snifter valve, a small volume of air, which is absorbed by the water during the period of its passing through the valves, being churned up behind the piston, as it travels up to the top limit of its stroke. On the return stroke, the water is forced through the delivery-valve, one-half being discharged into the power-main, while the other half follows the descending bucket, and in turn is discharged into the power-main on the upstroke of the pump. Hence there is a single-acting suction and a double delivery giving a continuous feed of water into the power-main.

A pipe, fitted with an ordinary hand-wheel stop-valve, is led from the power-pipe to the water-tank, so as to act as a by-pass and permit of the engine being started free of load, and of the load being gradually applied while the engine is running.

It is natural to expect that with so extensive a system a slight leakage must take place at the stuffing-boxes, etc., and, on an average, there is a leakage of 14 gallons of water per shift of 18 hours.

No. 2 Power-engine.—A duplicate power-engine has been erected, for use in case of a breakdown, or of repairs requiring to be executed upon the No. 1 power-engine. It is a vertical compound condensing-engine, having high-pressure and low-

pressure cylinders respectively 16 inches and 26 inches in diameter and a stroke of 20 inches. Steam is applied at a boiler-pressure of 100 pounds per square inch, and arranged to cut off at 0·625 of the stroke in the high-pressure cylinder. The cranks are set at right angles, and a flywheel is fitted on the crank-shaft. The average number of revolutions per minute is 66. It is fitted with automatic appliances to prevent racing of the engine and mishaps to the pipes and joints, and, in addition, with a steam-accumulator. This accumulator is not needed at Loanhead colliery under the present conditions, since the power is required to be constant, but it is a very useful appliance where intermittent working of the plant is unavoidable, as was the case when the haulage-motor was working. The power-pumps are 4½ inches in diameter, and are of the bucket-and-

Fig. 6.—The Hathorn-Davey Duplex Hydraulic Pump.

plunger type, having the pump-rods attached direct to the piston-rods of the engine. The brass suction-valves and delivery-valves are of the conical type. The power-main and return-mains are 3¾ inches and 4 inches in diameter respectively. The *modus operandi* is similar to that of No. 1 power-engine.

Mine Pumps.—Installed at the bottom of the shaft, at a distance of 1,620 feet on the slope from the power-engine, is a Hathorn-Davey duplex hydraulic pump (Fig. 6). This gear presents a novelty in its adaptation to mining purposes at Loanhead colliery.

Figs. 1 and 2 (Plate III.) shew, in elevation and plan, the construction of the gear. The arrangement consists of four pumps of the plunger-type, A, B, C and D (Fig. 2), having rams 9½ inches in diameter. The pumps, A and D, and B and C, each constitute a pair in tandem, and are arranged in parallel on each side of the centre line of the pump. In Fig. 1, the pump barrel and motor-ram barrel are shown in section. The ram, K, 9½ inches in diameter, is extended into the motor-barrel, where a connection is made to a rod, 5½ inches in diameter. The annular area, thus formed, constitutes the motor-ram, and is equivalent to the area of a plain ram, 7¾ inches in diameter. The opposite end of the pump is similarly arranged. The two rods, 5½ inches in diameter, are brought close to one another, and connected by means of a coupling, L, thus forming a double-action twin pump. The pump barrels and motor-ram barrels are made of cast-iron. The rams are made of cast-iron, overlaid with gun-metal, and the connecting rods are made of steel. The suction-valves and delivery-valves are of the disc-type and made of cast-iron with anti-friction white-metal beats. An air-vessel is placed on the suction-pipe. The suction-pipes and delivery-pipes are cast in one piece with the power and pump ends, so as to constitute the whole machine into a rigid girder, not likely to get out of alignment even although the foundation-bolts should give way.

In order to avoid over-travel of the plungers, and to prevent them from knocking against the ends of the barrels, which would occur if the pump lost its water or the motor-power valve remained too long open, due to any excessive friction, a portion at one end of each of the motor-ram barrels was bored to fit

the motor-ram (Fig. 3, Plate III.). When the ram reached this point, on the exhaust stroke, the water was imprisoned in the end of the ram-casing, only so much exhausting as could escape between the ram and the bored portion of the casing. The speed of travel of the ram was, therefore, greatly reduced and finally the ram was brought to a stop, the buffer, Y, resting against the end-cover. A by-pass valve, X, and a fluted washer, Z, were also provided so as to enable the water to get easily to the back of the ram to make the return-stroke.

This inside cushioning gear, however, has been dispensed with and an outside cushioning gear (Fig. 4, Plate III.) substituted, consisting of indiarubber rings, R, and a striking cover, S, against which the coupling of the rods comes in contact, and compresses, when through some cause an abnormal condition is set up in the pump. The buffers are compressed by about 1 inch, when the coupling of the rods strikes a cover. This outside arrangement is much easier of access when repairs are necessary.

The motor-valve (Fig. 5, Plate III.), the most important detail of the pump, is of the beat type, consisting of a mushroom-shaped power-valve, M, connected to the valve-rod, and an annular exhaust-valve, N, working inside of two slotted cylindrical pieces, O and P, through which the power-water enters and escapes from the motor-valve. The power-valve, M, rests against the inside face, Q, of the exhaust-valve, when the power-supply is cut off, and the exhaust-valve rests against the face, R, when the exhaust is cut off. A U-shaped leather, S, is fitted between the cylindrical slotted pieces so as to prevent the passage of power-water to the return-main. The power-water is introduced to the valve-casing through the branch-pipe, T, which is connected to the power-main, and enters the motor-cylinder through the branch-pipe, U. The exhaust-water is passed to the return-main, after completing its work in the motor-cylinder, through the branch-pipe, V.

The valve-casings are constructed to work against heavy pressures, every valve is easy of access, and may be readily got at for renewals or repairs. There are four motor-valves, W, X, Y and Z (Fig. 2, Plate III.), two on each side, and each pair of power-valves are connected by means of a rod, VR (Fig.

1, Plate III.). The motor-valves derive their motion from an arrangement of levers, VL_1 and VL_2 (Fig. 2, Plate III.), the ends working in swivelling collars fitted to the couplings, L_1 and L_2, of the ram-rods. The valve-lever, VL_1, extends across the pump, and obtains its motion from the ram opposite to the valve-gear that it is operating. The swivelling collar for the lever, VL_1, is fitted to the bottom side of the ram-rod coupling, L_1. The other lever, VL_2, also extends across the pump, its swivelling collar being arranged on the top side of the other coupling, L_2. The other ends of these levers are attached to the mid-points of the rods connecting the power-valves. In the one case, the lever, VL_1, is of the second order, while in the other, the other lever, VL_2, is of the first order.

The construction of the pump, independent of the motor-valves, is of the simplest kind, there being no intricate parts in connection with them. The various parts of the pump are so arranged, that, in the case of a renewal, the defective part can be easily removed and the new part replaced without disturbing the arrangement of the pump as a whole.

In order to explain the motion of the pump, let it be supposed that it is in the position shewn in Fig. 2 (Plate III.), that is, with the plunger, A, and its motor-ram, E, at the end of their discharge- and power-strokes; and the other plunger, D, and the motor-ram, H, on the same side, at the end of their suction- and exhaust-strokes. On the other side of the pump, the plungers, B and C, and their motor-rams, F and G, will be at half-stroke. It follows, therefore, that, owing to the position of the plungers, A and D, at the end of their strokes, the position of the lever, VL_2, will be such that it has the motor-valve, X, open to the power-water and the motor-valve, Y, open to the exhaust. Owing to the position of the plungers, B and C, at half stroke, and to the consequent central position of the lever, VL_1, the motor-valves, W and Z, will be closed to the power-water and to the exhaust. If, now, the pump move, the result will be that, owing to the plungers, B and C, moving in the direction from C to B, the lever, VL_1, will make the power-valve of Z leave the face, Q, of the exhaust-valve, and, thereby, allow the power-water to pass through the inside of the exhaust-valve, and into the motor-ram barrel, H, thereby putting it on its power-

stroke. Simultaneously, the power-valve of W moves against the inside face, Q, of the exhaust-valve and propels the exhaust-valve forward, allowing the water to pass into the return-main, thereby putting the motor-ram, E, and the plunger, A, on their exhaust- and suction-strokes. The plunger, B, is now on the discharge-stroke and the motor-ram, F, is receiving pressure, while the plunger, C, is on its suction-stroke and the motor-ram, G, is on the exhaust-stroke. Consequently, the direction of motion is from A to D, and when the rams, A and D, have moved sufficiently far to bring the lever, VL_2, to its mid-position, the opposite rams, B and C, will have reached the end of their strokes. But, owing to the motion from A to D, the valve-lever, VL_2, is still being carried in that direction, ultimately opening the valve, X, to the exhaust and the valve, Y, to the pressure-water, thereby putting the plunger, B, on its suction-stroke and the plunger, C, on its discharge-stroke. Consequently, from the above-described action of the valves, it is impossible for both the exhaust-valve and the power-valve at the same end of the pump to be open at the same time, since the opening of the exhaust-valve is performed by the power-valve, which cannot operate upon it until after the power-opening has been closed.

The pump was originally designed to work at a lower level, but it has been raised to suit the conditions of the colliery; and therefore the power-plunger area is larger than would have been the case had the pump been originally intended for its present position. The pump delivers 300 gallons of water per minute against a head of 660 feet, through delivery-pipes 8 inches in diameter. The length of the stroke is 4 feet.

This paper describes the conditions under which the pump is working at Loanhead colliery, but, given a sufficient supply of power-water at a pressure of 1,000 pounds per square inch, this pump could be applied against much greater heads than 660 feet.

As the speed of the water is comparatively slow, there is little loss of power due to the necessary bending of the pipes, in some positions. No trouble is experienced in keeping the arrangement working regularly and well; and, when working at a speed of 5 strokes per minute it may be said to be automatic, as the whole arrangement may be set in motion and kept going for a time without a single attendant underground, two men being able to superintend the whole plant per shift.

The plumbago-packing, in use, is well adapted for withstanding the high pressures, such as exist in the power-cylinders.

The weight of small coal consumed is only 40 per cent. of that used by the old method; but, as the old system of raising the water was very imperfect, the comparison shows a far greater contrast than would actually be the case with a well-designed and well-equipped steam-plant.

The writer is, however, decidedly of opinion that, when water has to be raised through high vertical heads, and pumping has to be carried out in dip-workings, the hydraulic system holds out advantages which compare favourably with any system yet in operation. There are no expensive pump-rods to keep in repair, and no heat generated which renders the use of steam so objectionable. Hydraulic pumps can be worked, even when submerged in water, they are well adapted to meet the exigencies of fiery mines, they have a higher useful efficiency than compressed air, and the only pumps that may be said to sustain a just comparison with them are electric pumps; and, even with all their claims to attention, the writer believes that under the conditions above-mentioned no other method at present in operation may be said to possess the same advantages.

On an average, the mechanical efficiency in water lifted by these hydraulic pumps varies from 50 to 70 per cent. of the indicated power of the pressure produced by the engine on the surface.

A Brown hydraulic pump is placed 6 feet above the level of the Hathorn-Davey pump, and acts as a stand-by, in case of a breakdown, or of repairs requiring to be executed upon the Hathorn-Davey pump. Further comment on the Brown pump is unnecessary, as a description has already appeared in the *Transactions*.*

The CHAIRMAN (Mr. James Hamilton) said he understood, when this installation was started, that considerable difficulty was experienced with the packing of the rams. Not the least useful feature of a paper such as this was to record even minor difficulties of detail and how they were overcome. If Mr. Crawford could supplement his paper in this way, it would be extremely useful to the members.

* "The Brown Hydraulic System for Underground Pumping and Haulage," by Mr. W. F. Lang, *Trans. Inst. M. E.*, 1897, vol. xiv., page 47.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

EXCURSION MEETING,
DARLINGTON, JULY 19TH, 1905.

THE BARTON AND FORCETT LIMESTONE-QUARRIES.

BY THOMAS TEASDALE.

I.—BARTON LIMESTONE-QUARRIES.

The Barton quarries are situated 6 miles south-west of Darlington, in the North Riding of Yorkshire, and are 340 feet above sea-level. They are connected with the Darlington and Barnard Castle branch of the North-eastern Railway by the Merrybent Railway, originally built in 1859 to serve the Merrybent copper-mines and limestone-quarries.

The quarries now being worked were reopened in 1895, and give employment to about 110 workpeople.

The beds of limestone worked by the Barton Limestone Company, Limited, lie below the Great limestone in the Carboniferous Limestone series, and are almost wholly formed of encrinites (Fig. 1)*, which exhibit, on fracture, a white, crystalline and pearly appearance or lustre (Fig 2). The encrinite-beds attain a thickness of 36 feet, but this is not constant; nor is the thickness of the various beds forming the whole, for sometimes a bed at one point may only be 3 feet thick, whilst the same bed 100 feet away may be 12 or 14 feet thick, and so on, each bed constantly varying in thickness in every direction.

The limestone is chiefly quarried for use in the Cleveland blast-furnaces of the Middlesborough district; but lately it has been discovered that the stone has a high electrical resistance, and on that account it has been used as ballast upon electrified railways.† This ballast, of a suitable size, is produced by pass-

* This illustration has been reproduced, by permission, from *Zig-zag Ramblings of a Naturalist*, 1898, by Dr. R. Taylor Manson. page 143.

† *Trans. Inst. M. E.*, 1905, vol. xxx., pages 99 and 104.

ing the stone through a crushing and screening plant, which was originally erected to manufacture roadstone, and is capable of crushing 200 tons of limestone daily.

The encrinital limestone rests upon the Trindall blue limestone.

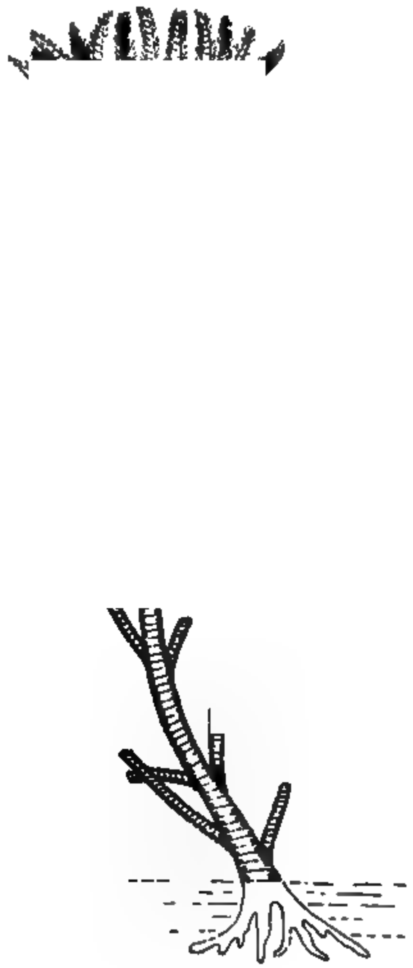

FIG. 1.—*POTERIOCRINUS CRASSUS.*

The late Dr. R. Taylor Manson and the officers of the Geological Survey state that "the quarry at Barton is in that division of the Yoredales known as the Undersett or Four-fathoms limestone,"* and Dr. Manson also states that the encrinite found at Barton is *Poteriocrinus crassus*.†

The beds in the quarry are somewhat uncertain as to quality: a bed may be good white pure limestone, and a few feet distant, without break or line of demarcation, it may become very impure, highly siliceous, blue stone, of no value whatever for metallurgical purposes; and it is then sent to the stone-crusher.

The crushing-plant (Fig. 3) comprizes two stone-breakers, one 25 inches by 14 inches, and the other 21 inches by 10 inches, into which the rough stone is fed from the wagons. When crushed, it falls into a pit, from which it is elevated to a sufficient height for screening purposes. The stone is delivered by the

* *Zig-zag Ramblings of a Naturalist*, 1898, page 149.

† *Ibid.*, page 142.

elevators into a double-cone revolving screen; the inner screen throws the "rejects" into a shute, while the outer screen takes out all stone of the 2¼ inches size. The remainder of the crushed stone passes through this latter screen into a shute, and on to a long cylindrical screen, which extracts the dust and separates the stone into various sizes, from ¼ inch to 2 inches. The "rejects" are passed through a pair of rolls, 18 inches in diameter, and reduced to fine sizes, which are re-elevated and passed into the long cylindrical screen. Hoppers, with a capacity of 50 tons,

FIG. 2.—BARTON LIMESTONE-QUARRIES: ENCRINITAL LIMESTONE.

are built under the screens. The railway wagons are filled, by sliding doors, from these hoppers. The plant is driven by a semi-portable engine, with two cylinders, 14 inches in diameter, and a boiler working at a pressure of 75 pounds per square inch.

The north and best face (Fig. 4) in the quarry is over 32 feet thick, and analyses of the several posts are recorded in Table I.

TABLE I.—THICKNESSES AND ANALYSES OF THE POSTS OF LIMESTONE IN BARTON QUARRY.

Beds or Posts.	Thicknesses of Beds.	Analyses.			
		Carbonate of Lime.	Silica.	Carbonate of Magnesia.	Totals.
	Ft. Ins.	Per cent.	Per cent.	Per cent	Per cent
First or top . .	11 0	96·37	1·20	1·59	99·16
Second	6 9	94·94	1·80	1·90	98·64
Third	7 8	97·80	1·80	1·28	100·85
Fourth . .	7 0	96·72	2·30	1·11	100·13
Total and averages	32 5	96·46	1·77	1·47	99·70

FIG. 3. BARTON LIMESTONE-QUARRIES: STONE-CRUSHING PLANT.

On examining the face of the quarry, the joints, backs and cracks, and more or less horizontal strata, lines of nodules, and thin layers of a material, which is not limestone, are to be seen, at various parts, running parallel to the planes of bedding. If

some of this material be broken, it is found to be a greyish-white, compact, flinty mass, with a smoother fracture than the rock in which it is embedded or intercalated. This substance is a flint or chert, and contains 83 per cent. of silica. Generally, the limestone in which the flint or chert is embedded is also itself of a highly siliceous character. The photograph (Fig. 5) shews the flint projecting from a back or cheek of the quarry.

FIG. 4.—BARTON LIMESTONE-QUARRIES: NORTH FACE.

The photograph (Fig. 6) shews a piece of the encrinital limestone taken out of a clay-back or joint in the limestone, with the encrinites standing out boldly from it. It would appear that some chemical solvent had dissolved away the body of the stone, leaving the encrinites embossed or projecting in relief.

The course of the Merrybent copper-vein passes through the west gullet-road and the west end of the north face, and whether

the influence of the vein has died out or broken up remains unknown, but it will probably be proved when the north face is worked northward. On the line of the vein in the west gullet-road and for some distance on each side, in the west gullet-road and in the north face, thick clay-backs were found, and joints and thick clay-beds; and sometimes the clay-joints pass diagon-

Fig. 5. Barton Limestone-quarries: Chert-bands in Encrinital Limestone.

ally upwards through the limestone-beds. The stone on the line of the vein contains from 4 to 12 per cent. of silica and from 1½ to 3½ per cent. of carbonate of magnesia, and is consequently totally unfit for blast-furnace purposes.

On the west side of the Watling street or Roman road is the Trindall blue-limestone quarry, also belonging to the Barton Limestone Company, Limited, but it is not at present being

worked. The stone is of an impure quality, containing from 3·8 to 8·6 per cent. of silica and from 1·04 to 8·15 per cent. of carbonate of magnesia, and it is only of value for road-making purposes.

The quarrymen, on the average, produce about 7 tons of stone per man per day, broken to pass through a ring 8 inches in diameter; and one price is paid for quarrying from the top to the bottom beds of the quarry.

FIG. 6.—BARTON LIMESTONE-QUARRIES: ENCRINITAL LIMESTONE.

Mr. E. Lyall is of opinion that the encrinital limestone forms part of the Red-beds limestone of Swaledale, and lying about 54 feet, according to Mr. Lonsdale Bradley, above the Great limestone.

The encrinital limestone at Barton appears to be a purely local deposit. The writer has not seen the Red-beds limestone

in Swaledale, but he thinks that the late Dr. Manson and the officers of the Geological Survey must have obtained sufficient proof before mapping the bed as the Undersett or Four-fathoms limestone.

FIG. 7.—FORCETT LIMESTONE-QUARRIES: FORCETT SIDE.

II.—FORCETT LIMESTONE-QUARRIES.

The Forcett quarries lie about 3½ miles (as the crow flies) north-west of the Barton quarries, and are worked in the Great limestone of the Yoredale series in Weardale, Teesdale, Alston and Swaledale. A section of this limestone is detailed in Table II

Figs. 7 and 8 shew the Forcett and East Layton districts of the Forcett quarries.

An average analysis of the beds, now being worked, is as follows:—Carbonate of lime, 96·00 per cent.; silica, 2·00 per

cent.; carbonate of magnesia, 1·80 per cent.; and oxide of iron, a trace.

The brown bed, and Newcastle and bottom posts are not worked, as the stone is somewhat inferior; and occasionally the Whaley

FIG. 8.—FORCETT LIMESTONE-QUARRIES: EAST LAYTON SIDE.

TABLE II.—THICKNESS OF THE POSTS OF LIMESTONE IN THE FORCETT QUARRIES.

Local Names of each Post or Bed.	Thicknesses of Beds. Ft.	Ins.	Ft.	Ins.
Working beds:				
Top bed	3	0		
Silver post	3	9		
Crabby	4	0		
Scraps	1	6		
Wooley Topping ...	1	6		
Thick post	3	6		
White post . .	3	8		
Brown George ..	2	0		
John	2	8		
Thin beds	5	0		
Base Whaley	2	0		
Black Jack	0	9		
			33	4
Bottom beds:				
Brown bed ...	2	9		
Newcastle post ...	1	10		
Bottom post	1	8		
			6	3
Total			39	7

post is of no value for metallurgical purposes, and is thrown away. The quarrymen's benching is formed on the top of the Brown George post. The top part of the quarry down to this benching is paid ½d. per ton less than the bottom part, as a basis-rate.

About 130 persons are employed, and the weekly output of about 3,000 tons is all sent into the Cleveland district. The stone is expected to be broken to pass through a ring, 8 inches in diameter.

III.—Remarks.

Mr. J. G. Goodchild has correlated the limestone-beds of the Alston and Wensleydale districts as detailed in Table III.

Table III.—Correlation of the Limestones of the Yoredale Series.

Yoredale or Wensleydale District.	Alston District.
Crow.	Fell-top.
......	Crag.
Red-beds.	Little.
Main.	Great, Main or Twelve-fathoms.
Undersett.	Four-fathoms or Undersett.
Third Sett.	Three-yards.
Fourth Sett.	Five-yards.
Middle or Fifth Sett.	Scar.
Simonstone or Simonside.	Cockle-shell.
Sixth Sett.	Single-post.
Hardra or Hardrow.	Tyne-bottom.
Seventh Sett.	Jew.

Table IV. contains a section, and records the local names of the posts in a typical Great limestone-quarry in Weardale, and for the sake of comparison it is extended to and includes the Four-fathoms limestone of that district. The Great limestone is composed of a series of rock-leaves, locally denominated "posts," and amongst the quarrymen each leaf or layer has its name, derived from some feature characteristic of the particular post to which it is applied. As a geological student knows each system of rocks by its composition, so the quarryman, by its nature and appearance, is familiar with each post of the stratum at which he labours. The limestone is a compact rock of blue, grey, greyish-white, or black colour. An average analysis of the limestone in Weardale is as follows:—Carbonate of lime, 94·89 per cent.; carbonate of magnesia, 1·60 per cent.; alumina, 1·05 per cent.; oxide of iron, 0·45 per cent.; silica, 1·45 per cent.; and moisture, 0·56 per cent.

TABLE IV.—SECTION OF STRATA IN A WEARDALE LIMESTONE-QUARRY, WITH THE LOCAL NAMES AND THICKNESSES OF EACH BED.

No. of Bed.	Local Names of Beds.	Thicknesses of Beds. Ft.	Ins.	Ft.	Ins.
	Plate				
	Tumbler Beds:				
26	Very top post ...	1	8		
25	Fourth post above the plate ...	3	8		
	Plate	1	0		
24	Third post above the plate ...	2	4		
	Plate	1	6		
23	Second post above the plate ...	1	9		
22	First post above the plate ...	1	9		
	Plate	1	2	14	10
	Great Limestone:				
21	Top grey post ...	2	2		
20	Fourth grey post ...	1	2		
19	Third grey post ...	3	8		
18	Second grey post ...	1	0		
17	Bottom grey post ...	4	0		
16	Crabby	8	0		
15	Three Dirty or Muckey posts ...	3	7		
14	Elsie	3	7		
13	Thin Cockle	1	1		
12	Thick Cockle ...	1	7		
11	Three black beds ...	4	6		
10	Five thin posts ...	2	10		
9	Dun Kit	4	6		
8	Three bastards ...	3	10		
7	Dun Jim	2	2		
6	Stiff Dick	1	1		
5	Whaley	3	7		
4	Jack post	0	6		
3	Yard post	2	10		
2	Newcastle post ...	1	6		
1	Bottom post	2	3	59	5
	Tuft or water sill ..	5	0		
	Quarry hazle... ...	67	0		
	Plate	24	0	96	0
	Four-fathoms Limestone	23	0	23	0
	Total			193	3

A cordial vote of thanks was accorded to the owners, and to Mr. E. Lyall and Mr. B. Abbott, the respective managers of the Barton and Forcett quarries.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

ANNUAL GENERAL MEETING,

HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE, AUGUST 5TH, 1905.

MR. T. W. BENSON, PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, and reported the proceedings of the Council at their meetings on July 22nd and that day.

ELECTION OF OFFICERS, 1905-1906.

The PRESIDENT (Mr. T. W. Benson) appointed Messrs. Norman B. Ridley, T. R. Ridpath, F. R. Simpson and W. B. Wilson, junr., as scrutineers of the balloting-papers for the election of officers for the year 1905-1906.

The SCRUTINEERS afterwards reported the result of the ballot, as follows:—

PRESIDENT:

Mr. T. W. BENSON.

VICE-PRESIDENTS:

Mr. FRANK COULSON.	Mr. T. Y. GREENER.	Mr. HENRY PALMER.
Mr. T. E. FORSTER.	Mr. J. H. MERIVALE.	Mr. M. W. PARRINGTON.

COUNCILLORS:

Mr. R. S. ANDERSON.	Mr. AUSTIN KIRKUP.	Mr. J. H. NICHOLSON.
Mr. C. S. CARNES.	Mr. HENRY LAWRENCE.	Mr. F. R. SIMPSON.
Mr. W. C. CARR.	Mr. C. C. LEACH.	Mr. JOHN SIMPSON.
Mr. BENJAMIN DODD.	Prof. HENRY LOUIS.	Mr. R. F. SPENCE.
Mr. M. H. DOUGLAS.	Mr. JOHN MORISON.	Mr. SIMON TATE.
Mr. T. E. JOBLING.	Mr. W. C. MOUNTAIN.	Mr. R. L. WEEKS.

The President (Mr. T. W. Benson) moved a vote of thanks to the Scrutineers for their services.

Mr. M. Walton Brown seconded the resolution, which was cordially approved.

Mr. J. B. Simpson moved a vote of thanks to the Retiring President, Vice-Presidents and Councillors for their services during the past year.

Mr. Thomas Douglas seconded the resolution, which was cordially adopted.

Mr. Henry Lawrence proposed a vote of thanks to the representatives of the Institute on the Council of The Institution of Mining Engineers for their services during the past year.

Mr. T. W. English seconded the resolution, which was heartily adopted.

The Annual Report of the Council was read as follows:—

ANNUAL REPORT OF THE COUNCIL, 1904-1905.

It is the sad duty of the Council to refer to the great loss that the Institute has sustained through the death of Sir Lowthian Bell, Bart., a past-president of the Institute and a member since 1854. It is impossible to gauge the value of the work carried out by Sir Lowthian Bell, covering as it did a very wide field of scientific research, but the Council feel that the results of his investigations will be a lasting monument to his memory.

The following table shows the progress of the membership during the past few years:—

Year ending August 1st.	1901.	1903.	1905.
Honorary Members	28	26	24
Members	880	921	953
Associate Members	122	112	113
Associates	116	161	178
Students	57	69	56
Subscribers	23	23	28
Totals	1.226	1.312	1,352

Although 95 members of all classes have been added to the register during the past year, there has only been an increase of 2 members, owing to the exceptional losses by death, resignation, etc.

The Library has been maintained in an efficient condition during the year; the additions, by donation, exchange and purchase, include 562 bound volumes and 89 pamphlets, reports, etc., and the Library now contains about 10,510 volumes and 290 unbound pamphlets. A card-catalogue of the books, etc., contained in the Library renders them readily available for reference.

Members would render useful service to the profession, by presentations of books, reports, plans, etc., to the Institute, to be preserved in the Library and thereby become available for reference.

The courses of lectures for colliery-engineers, enginewrights and apprentice-mechanics have been continued at the Armstrong College, Newcastle-upon-Tyne. The lectures are delivered on Saturday afternoons, and the three years' course embraces the following subjects:—

1905-1906. Michaelmas Term, (1) Transmission of Power, and (2) Pumping and Ventilation. Epiphany Term, (3) Metallurgy of Iron and Steel, and (4) Mining Machinery (mainly machinery used underground).

1906-1907. Michaelmas Term, (5) Mensuration, and (6) the Chemistry of Fuel. Epiphany Term, (7) Strength of Materials (with experimental illustrations), and (8) Experimental Mechanics.

1907-1908. Michaelmas Term, (9) Theoretical Electricity, and (10) Electrical Engineering. Epiphany Term, (11) Steam-engines and Boilers, and (12) Haulage and Winding.

Several colliery-owners have paid the fees (£1 10s. per annum) and railway expenses of pupils attending the classes from their collieries. During the past year, the lectures of the Michaelmas Term on Theoretical Electricity were attended by 26 students, and Electrical Engineering by 27 students, 27 of whom sat for examination and 17 passed; and during the Epiphany Term, the lectures on the Steam-engine were attended by 24 students, and upon Haulage and Winding by 23 students, 20 of these were examined and 18 passed. Certificates have been awarded to the following students, who have completed the three years' course:—Messrs. W. C. Aynsley, James Wright Collingwood, J. W. Forbister, E. Jobes, J. Rowland and J. H. Thompson. Messrs. J. H. Thompson and E. Jobes, who gained

the highest aggregate number of marks, have been awarded first and second prizes respectively for the session 1904-1905.

G. C. Greenwell gold, silver and bronze medals may be awarded annually for approved papers "recording the results of experience of interest in mining, and especially where deductions and practical suggestions are made by the writer for the avoidance of accidents in mines."

The G. C. Greenwell bronze medal has been awarded to Mr. Henry Wallace Gregory Halbaum for his paper upon "The Action, Influence and Control of the Roof in Longwall Workings."*

Mr. John Daglish continues to represent the Institute as a governor of the Armstrong College, which was jointly founded in 1871 by the University of Durham and The North of England Institute of Mining and Mechanical Engineers; and Mr. T. E. Forster, in conjunction with the President (Mr. T. W. Benson), represents the Institute on the Council.

Mr. A. R. Sawyer will represent the Institute at the Conference of the Corresponding Societies of the British Association for the Advancement of Science, to be held in London, commencing on October 30th, 1905.

Mr. George May represents the Institute upon the Board of Directors of the Institute and Coal Trade Chambers Company, Limited.

The representatives of the Institute upon the Council of The Institution of Mining Engineers during the past year were as follows:—Sir Lowthian Bell, Bart., and Messrs. William Armstrong, Thomas Walter Benson, Bennett Hooper Brough, Arthur George Charleton, Thomas Douglas, George Clementson Greenwell, Reginald Guthrie, Thomas Edgar Jobling, Philip Kirkup, Charles Catterall Leach, William Logan, Henry Louis, Henry William Martin, George May, John Morison, Henry Palmer, Matthew William Parrington, Henry Richardson, Arthur Robert Sawyer, Frank Robert Simpson, John Simpson, John Bell Simpson, John George Weeks and William Outterson Wood.

Exchanges of *Transactions* have been arranged, during the year, with the Mid-Glamorgan Association of Colliery Managers and the Rugby Engineering Society.

* *Trans. Inst. M. E.*, 1904, vol. xxvii., page 205

Prizes of books have been awarded to the writers of the following papers, communicated to the members during the year 1903-1904:—

"Some Silver-bearing Veins of Mexico." By Mr. Edward Halse, M.I.M.E.
"Notes on Mining in Ireland." By Mr. G. H. Kinahan.
"Notes on Electric Power applied to Winding in Main Shafts." By Mr William Charles Mountain, M.I.M.E.
"An Improved Forced Method of Treatment of Low-grade Copper-ores." By Mr. John James Muir, M.I.M.E.
"The Adoption of a Balance-rope at Hylton Colliery." By Mr. Thomas Elliott Parrington, Assoc.I.M.E.
"Bore-holes for Pumping Purposes." By Mr. Edward Septimus Wight, M.I.M.E.

The papers printed in the *Transactions* during the year are as follows:—

"Observations on Water-sprayed or Damped Air in Coal-mines." By Mr. James Ashworth.
"The Mickley Conveyor." By Mr. John Wright Batey, M.I.M.E.
"The Action, Influence and Control of the Roof in Longwall Workings." By Mr. James Thom Beard, M.I.M.E.
"A Method of Packing Excavations in Coal-seams by Means of Water." By Mr. Edward Otto Forster Brown, Stud.I.M.E.
"Note on a Natural Paraffin found in the Ladysmith Pit, Whitehaven Collieries." By Mr. Roger Dodds.
"Note on the Composition of Coal from the Faröe Islands." By Mr. Roger Dodds.
"An Outbreak of Fire, and its Cause, at Littleburn Colliery." By Mr. Martin Forster Holliday, M.I.M.E.
"An Improved Watering-tub for Laying Dust in Coal-mines." By Mr. Henry Lawrence, M.I.M.E.
"Notes on Safety-lamp Oils." By Dr. George Percy Lishman, Assoc.M.I.M.E
"The Miners' Worm-disease, as seen in Westphalian and Hungarian Collieries." By Dr. Thomas Oliver.
"The Use of Concrete in the Working of Thick Coal-seams." By Mr. Joseph Hippolyte Piffaut.
"The Action, Influence and Control of the Roof in Longwall Workings." By Mr. Edward Heton Roberton.
"The Development of Explosives for Coal-mines." By Mr. Donald M. D. Stuart, M.I.M.E.
"Note on the Calorific Effect of Coal from the Faröe Islands." By Mr. R. R. Thompson.
"Note on the Composition of Dover Coal." By Mr. R. R. Thompson.

The following presentations have been received:—Mr. Thomas George Noble, safety-lamp recovered after the Lundhill colliery-explosion on February 19th, 1857; and Mr. Thomas Edgar Jobling, nine patterns of safety-lamps.

The rooms of the Institute have been used during the year by the Newcastle-upon-Tyne Literary and Philosophical Society for a conversazione in connection with the meeting of the Library Association in Newcastle-upon-Tyne.

Permission to attend and take part in the General Meetings has been granted to the Engineering Students at the Armstrong College.

During the past year, invitations to take part in an International Engineering Congress, in conjunction with the St. Louis Universal Exposition, 1904, and an International Congress of Mining, Metallurgy, Engineering and Applied Geology, in conjunction with the Universal Exposition at Liége, 1905, were received, and a number of the members availed themselves of these invitations.

Excursions have been made to various collieries, works, etc., in the district, in connection with the visit of members of the Association des Ingénieurs sortis de l'École de Liége, and also to the Barton and Forcett limestone-quarries.

With reference to the entry of circulars of the Institute into Australia, free of duty, the Collector of Customs at the Port of Sydney has been interviewed by Mr. Alfred Ashley Atkinson, Inspector of Mines, and the Collector of Customs at the Port of Melbourne has been interviewed by Mr. Edwin Richard Field, both acting on behalf of the Institute, with the result that it has been decided that notices of general meetings are entitled to free entry into Australia, and the thanks of the members are due to these gentlemen for their valuable assistance.

The Institution of Mining Engineers has now completed its sixteenth year, and the members are to be congratulated upon its continued success. Meetings have been held during the past year in the Nottingham district in September, 1904, and in London in June, 1905.

The PRESIDENT (Mr. T. W. Benson), in moving the adoption of the Annual Report of the Council, said that the members would agree that it was very satisfactory, and shewed that at any rate the Institute was doing good work. The Institute had sustained serious loss by the death of 23 members during the past year; they had also lost 37 members by resignation.

Mr. THOMAS DOUGLAS, in seconding the adoption of the report, said that it was a matter of great regret to observe so large a number of deaths of members during the year. He also referred to the payment of the fees of students attending the course of lectures for colliery-engineers by several colliery-owners; and he felt sure that, if it were more generally known, many colliery-owners would contribute in this way for the benefit of the young and rising men, who might otherwise not have the opportunity of attending the classes at Armstrong College.

The motion was adopted.

The Report of the Finance Committee was read as follows:—

ANNUAL REPORT OF THE FINANCE COMMITTEE.

The Finance Committee submit herewith a statement of the accounts for the twelve months ending June 30th, 1905, duly audited.

The total receipts were £2,874 3s. 10d. Of this amount, £75 was paid for life-compositions in lieu of annual subscriptions, and £58 7s. as subscriptions in advance, leaving £2,740 16s. as the ordinary income of the year, compared with £2,904 2s. 6d. in the previous year. The sum realized for *Transactions* sold was only £18 10s. 10d., as against £108 0s. 6d. in the year 1903-1904, while the amount received as ordinary current-year subscriptions was £2,295 7s. and arrears £186 6s., as compared with £2,316 12s. and £236 6s. respectively in the earlier period.

The total expenditure was £2,733 18s., in comparison with £2,757 10s. 1d. in the previous year. Expenses to the amount of £34 12s. 2d. have been paid in connection with the Coal-cutting Committee, and £52 has been devoted to prizes, including the Claghorn Prize of £10. The cost of printing the *Subject-matter Indices of Mining, Mechanical and Metallurgical Literature* and *General and Subject-matter Indices to the Transactions, Volumes I. to XXXVIII.—1852 to 1889*, includes the sum of £168 7s. 6d. paid in settlement of disputed accounts extending over some years; £20 16s. 8d. for receipt-stamps on banker's receipt-forms for subscriptions appears among the incidental expenses, and £55 11s. 6d. was expended in connection with the visit of the Association des Ingénieurs sortis de l'École de Liége. Decreases are shewn in the expenditure on books for the library,

postages, telegrams and telephones, compared with the accounts for the previous year, which also included £133 spent on the Lecture Theatre.

It will be seen, from the figures given above, that the total income exceeded the expenditure by £140 5s. 10d., and, adding this to the balance in hand at the beginning of the year, amounting to £415 13s. 3d., there is a sum of £555 19s. 1d. to carry forward.

The names of 39 persons have been struck off the membership list in consequence of non-payment of subscriptions. The amount of subscriptions written off was £183, of which £99 18s. was for sums due during the year ending June 30th, 1905, and £83 2s. for amounts which had fallen due in previous years. Some considerable proportion of this will, no doubt, be recovered by the solicitors; and, whatever sum is received, will be credited in future years. Of the amounts previously written off, £34 was recovered during the past year.

T. W. Benson.

August 5th, 1905.

Mr. J. B. Simpson, in moving the adoption of the Annual Report of the Finance Committee, said that the members would be rejoiced that the finances were in a good position, and that there was so substantial a balance to carry forward.

Mr. Henry Lawrence seconded the resolution, which was adopted.

THE G. C. GREENWELL MEDAL.

The President (Mr. T. W. Benson) in presenting the Greenwell bronze medal to Mr. H. W. G. Halbaum for his paper upon "The Action, Influence and Control of the Roof in Longwall Working," said that the writer had worthily earned the distinction, as the paper was of very considerable interest, and more especially as so much coal was worked by longwall methods.

Mr. H. W. G. Halbaum, in expressing his thanks for the honour, said that he would value the medal exceedingly, as shewing the good-will of the Institute, and also as a memorial of the fine old English gentleman whose name was associated with it.

DR. THE TREASURER IN ACCOUNT WITH THE NORTH OF ENGLAND

FOR THE YEAR ENDING

		£ s. d.	£ s. d.	£ s. d.
June 30th, 1904.				
To Balance at Bankers			359 18 3	
„ „ in Treasurer's hands			49 11 0	
„ Outstanding Accounts due from Authors for Excerpts			6 4 0	415 13 3
June 30th, 1905.				
To Dividend of 7½ per cent. on 179 Shares of £20 each in the Institute and Coal-trade Chambers Company, Limited, for the Year ending June 30th, 1905 ...			268 10 0	
„ Interest on Mortgage of £1,400 with the Institute and Coal-trade Chambers Company, Limited			49 0 0	317 10 0
To Sales of *Transactions*				18 10 10
To Donation to Library				2 2 0
To SUBSCRIPTIONS FOR YEAR 1904-1905 AS FOLLOWS:—				
758 Members	@ £2 2s.		1,591 16 0	
89 Associate Members	@ £2 2s.		186 18 0	
127 Associates	@ £1 5s.		158 15 0	
56 Students	@ £1 5s.		70 0 0	
63 New Members	@ £2 2s.		132 6 0	
2 New Members, not yet elected ...	@ £2 2s.		4 4 0	
7 New Associate Members	@ £2 2s.		14 14 0	
1 New Associate Member, not yet elected	@ £2 2s.		2 2 0	
16 New Associates	@ £1 5s.		20 0 0	
6 New Students	@ £1 5s.		7 10 0	
			2,188 5 0	
25 Subscribing Firms		£100 16 0		
3 New Subscribing Firms		6 6 0	107 2 0	
			2,295 7 0	
To LIFE COMPOSITIONS:—				
2 Members		£51 0 0		
1 New Member		24 0 0	75 0 0	
			2,370 7 0	
Less—Subscriptions for Current Year paid in advance at end of Last Year			78 19 0	
			2,291 8 0	
Add—Arrears received			186 6 0	
			2.477 14 0	
Add—Subscriptions paid in advance during the Current Year			58 7 0	2,536 1 0
				£3,289 17 1

INSTITUTE OF MINING AND MECHANICAL ENGINEERS — CR.
JUNE 30TH, 1905.

June 30th, 1905.		£ s. d.	£ s. d.
By *Annual Report*		35 1 3	
„ Banker's Charges		21 12 4	
„ Circulars and Advance Copies of Papers		61 5 11	
„ Cleaning Wood Memorial Hall, Offices, etc.		31 6 10	
„ Coal-cutting Committee		34 12 2	
„ Electric Light		27 6 8	
„ Expenses of Meetings		55 11 6	
„ Fire Insurance		13 5 9	
„ Fuel		21 11 8	
„ Furniture and Repairs		76 11 6	
„ Incidental Expenses		6 15 4	
„ Illustrations		12 19 6	
„ Library—Binding	£64 15 3		
„ „ Books	16 13 6		
		81 8 9	
„ Petty Cash		5 14 2	
„ Postages—Circulars	£42 9 11		
„ „ Correspondence	24 16 0		
„ „ Publications	17 17 1		
		85 3 0	
„ Prizes		52 0 0	
„ Rates and Taxes		5 16 3	
„ Rent of Offices		24 4 0	
„ Reporting of General Meetings		12 12 0	
„ Salaries, Wages, Auditing, etc.		517 14 6	
„ Stamps on Receipt-forms		20 16 8	
„ Stationery, etc.		48 3 1	
„ *General and Subject-matter Indices to Transactions*, etc.		171 12 6	
„ Telephone Rent		2 18 4	
„ Travelling Expenses		0 15 0	
„ Water Rate...		4 13 0	
			1,431 11 8
By The Institution of Mining Engineers		1,306 11 4	
Less—Amount paid by Authors for Excerpts ...		4 5 0	
			1,302 6 4
			2,733 18 0
By Balance at Bankers		500 17 11	
„ „ in Treasurer's hands		47 12 8	
„ Outstanding Accounts due from Authors for Excerpts		7 8 6	
			555 19 1
			£3,289 17 1

We, having examined the above account with the books, vouchers and securities relating thereto, certify that, in our opinion, it is correct.

JOHN G. BENSON AND SONS,
CHARTERED ACCOUNTANTS.

Newcastle-upon-Tyne, August 1st, 1905.

Dr. The Treasurer of the North of England Institute of Mining

	£	s.	d.	£	s.	d.	£	s.	d.
To 955 Members,									
52 of whom have paid Life-compositions.									
903									
2 not included in printed list.									
905 @ £2 2s. ...	1,900	10	0						
2 Members paid Life-composition ...	51	0	0	1,951	10	0			
907									
To 115 Associate Members,									
8 of whom have paid Life-compositions.									
107 @ £2 2s.				224	14	0			
To 163 Associates,									
1 of whom has paid a Life-composition.									
162									
4 paid as New Members.									
158 @ £1 5s.				197	10	0			
To 66 Students @ £1 5s.				82	10	0			
To 25 Subscribing Firms				100	16	0	2,557	0	0
To 63 New Members @ £2 2s. ...	132	6	0						
To 1 New Member paid Life-composition ...	24	0	0						
To 2 New Members, not yet elected @ £2 2s.	4	4	0	160	10	0			
66									
To 7 New Associate Members @ £2 2s.	14	14	0						
To 1 New Associate Member, not yet elected	2	2	0	16	16	0			
8									
To 16 New Associates @ £1 5s.				20	0	0			
To 6 New Students @ £1 5s.				7	10	0			
To 3 New Subscribing Firms @ £2 2s.				6	6	0	211	2	0
							2,768	2	0
To Arrears, as per Balance Sheet 1903-1904				309	18	0			
Add—Arrears considered irrecoverable, but since paid...				34	0	0	343	18	0
							3,112	0	0
To Subscriptions paid in advance							58	7	0
							£3,170	7	0

AND MECHANICAL ENGINEERS IN ACCOUNT WITH SUBSCRIPTIONS, 1904–1905. CR.

		PAID. £ s. d.	UNPAID. £ s. d.	STRUCK OFF LIST. £ s. d.
By 758 Members, paid	@ £2 2s.	1,591 16 0	......	......
By 2 " paid Life-composition		51 0 0	......	......
By 108 " unpaid ...	@ £2 2s.	......	226 16 0	...
By 7 " excused payment	@ £2 2s.	......	......	14 14 0
By 4 " dead	@ £2 2s.	......	......	8 8 0
By 28 " struck off list	@ £2 2s.	......	......	58 16 0
907				
By 89 Associate Members, paid	@ £2 2s.	186 18 0	......	......
By 13 " " unpaid	@ £2 2s.	......	27 6 0	.....
By 5 " " struck off list ...		......	......	10 10 0
107				
By 127 Associates, paid	@ £1 5s.	158 15 0	......	......
By 25 " unpaid ...	@ £1 5s.	......	31 5 0	......
By 6 " struck off list	@ £1 5s.	......	......	7 10 0
158				
By 56 Students, paid	@ £1 5s.	70 0 0	......	......
By 10 " unpaid ...	@ £1 5s.	......	12 10 0	......
66				
By 25 Subscribing Firms, paid		100 16 0	......	......
By 63 New Members, paid ...	@ £2 2s.	132 6 0	......	......
By 1 New Member, paid Life-composition		24 0 0	......	......
By 2 New Members, not yet elected, paid	@ £2 2s.	4 4 0	......	......
66				
By 7 New Associate Members, paid	@ £2 2s.	14 14 0	......	......
By 1 New Associate Member, not yet elected, paid ...	@ £2 2s.	2 2 0	......	......
8				
By 16 New Associates, paid ...	@ £1 5s.	20 0 0	......	......
By 6 New Students, paid ...	@ £1 5s.	7 10 0	......	......
By 3 New Subscribing Firms, paid	@ £2 2s.	6 6 0	......	......
		2,370 7 0	297 17 0	99 18 0
By Arrears		186 6 0	74 10 0	83 2 0
		2,556 13 0		
By Subscriptions paid in advance		58 7 0	......	......
		2,615 0 0	372 7 0	183 0 0
				372 7 0
				2,615 0 0
				£3,170 7 0

The North of England Institute of Mining and Mechanical Engineers: General Statement, June 30th, 1905.

Liabilities.

	£	s.	d.	£	s.	d.
Subscriptions paid in advance during the current year	58	7	0			
Ditto. in previous year	2	2	0			
				60	9	0
The Institution of Mining Engineers				18	16	3
Printing, etc.				70	0	0
The George Clementson Greenwell Prize Fund	100	0	0			
Less—Paid for Medals	67	8	4			
				32	11	8
Capital				11,735	11	6
				£11,917	8	5

We, having examined the above account with the books, vouchers and securities relating thereto, certify that, in our opinion, it is correct. We have accepted the assets, books, pictures, maps, etc., and *Transactions* and other Publications as valued by your Officials.

JOHN G. BENSON AND SONS,
Chartered Accountants.

Newcastle-upon-Tyne,
August 1st, 1905.

Assets.

	£	s.	d.	£	s.	d.
Balance of Account at Bankers	500	17	11			
„ in Treasurer's hands	47	12	8			
Outstanding Accounts due from Authors for Excerpts	7	8	6			
				555	19	1
Arrears of Subscriptions				372	7	0
179 Shares in the Institute and Coal-trade Chambers Company, Limited (at cost) ...	4,100	0	0			
Investment with the Institute and Coal-trade Chambers Company, Limited (mortgage) ...	1,400	0	0			
				5,500	0	0
(Of the above amount, £1,586 is due to Life-subscriptions Account.)						
Value of *Transactions* and other Publications, as per Stock Account	339	2	4			
Books, Pictures, Maps, Furniture and Fittings	5,150	0	0			
				5,489	2	4
				£11,917	8	5

REPRESENTATIVES ON THE COUNCIL OF THE INSTITUTION OF MINING ENGINEERS, 1905-1906.

The PRESIDENT (Mr. T. W. Benson) moved, and Mr. THOMAS DOUGLAS seconded, a resolution that the following gentlemen be elected as the representatives of the Institute on the Council of The Institution of Mining Engineers for the year 1905-1906:—

Mr. WILLIAM ARMSTRONG.
Mr. J. B. ATKINSON.
Mr. T. W. BENSON.
Mr. W. C. BLACKETT.
Mr. BENNETT H. BROUGH.
Mr. JOHN DAGLISH.
Mr. M. H. DOUGLAS.
Mr. T. E. FORSTER.
Mr. T. Y. GREENER.
Mr. G. C. GREENWELL.
Mr. REGINALD GUTHRIE.
Mr. PHILIP KIRKUP.
Mr. C. C. LEACH.
Prof. HENRY LOUIS.
Mr. GEORGE MAY.
Mr. J. H. MERIVALE.
Mr. JOHN MORISON.
Mr. W. C. MOUNTAIN.
Mr. J. H. NICHOLSON.
Mr. A. R. SAWYER.
Mr. JOHN SIMPSON.
Mr. R. F. SPENCE.
Mr. JOHN G. WEEKS.
Mr. R. L. WEEKS.
Mr. W. O. WOOD.

The resolution was agreed to.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

MR. GEORGE FRANCIS ADAMS, Inspector of Mines in India, 6, Dacres Lane, Calcutta, India.

MR. ALFRED LIONEL ATTWOOD, Mechanical Engineer, Remolinos, por Pedrola, Provincia de Zaragoza, Spain.

MR. WILLIAM WALTER CASSON, Mine-manager, St. Bees, R.S.O., Cumberland.

MR. JOHN MILNES FAVELL, Colliery Manager, Shotton Colliery, Castle Eden, R.S.O., County Durham.

MR. FRITZ HEISE, Bergschuldirector, Hernerstrasse 45, Bochum, Germany.

MR. JAMES BATEMAN KITCHIN, Mine-manager, Gillfoot, Egremont, R.S.O., Cumberland.

MR. RICHARD HENRY LOVELOCK LEE, Professor of Mining and Mechanical Engineering, The Imperial University, Tai Yuan Fu, Shansi, North China, *via* Peking.

MR. MIGUEL ARROJADO RIBEIRO LISBOA, Mining and Civil Engineer, Rua Costa Gama, Villa Japurá, Petropolis, Rio de Janeiro, Brazil, South America.

MR. JOHN SHANKS, Mining Engineer, 10, Church Road, Harrington, R.S.O., Cumberland.

MR. ROBERT STEEL, Colliery Manager, Woodhouse, Whitehaven, Cumberland.

MR. ARCHIBALD THOM, JUN., Colliery Manager, Moresby Parks, near Whitehaven.

MR. FREDERICK WILLIAM WIGHT, Mining Engineer, 5, Bondicar Terrace, Blyth, Northumberland.

ASSOCIATE MEMBERS—

MR. EDWARD ERSKINE BIRD, 16, Great George Street, Westminster, London, S.W.

MR. BENJAMIN ATHERTON HAMPSON, Hampsons Collieries, Dingley Dale, *via* Waschbank, Natal, South Africa.

ASSOCIATES—

MR. THOMAS BEWLEY, Under-manager, 122, Tamworth Road, Newcastle-upon-Tyne.

MR. CHARLES ANTHONY NELSON, Mining Engineer, c/o Mr. Henry C. Embleton, 7, Central Bank Chambers, Leeds.

MR. GEORGE TWEDDELL, Back-overman, 51, Double Row, Seaton Delaval, R.S.O., Northumberland.

STUDENT—

MR. CLAUD ALLEYNE ROBINSON, Articled Mining Engineer, Barngill House, Distington, Workington, Cumberland.

SUBSCRIBER—

DOMINION COAL COMPANY, LIMITED, Glace Bay, Nova Scotia, Canada.

Mr. G. C. WOOD'S paper on the "Determination of the Specific Electrical Resistance of Coals, Ores, etc.," was read as follows:—

DETERMINATION OF THE SPECIFIC ELECTRICAL RESISTANCE OF COAL, ORES, ETC.

By G. C. WOOD, B.Sc.

Preface by Prof. H. Stroud, M.A., D.Sc.

Last summer, it appeared to the Council of the Institute that it was very desirable to have an accurate knowledge of the electrical resistance of coal, as well as of the rocks above and below any given seam of coal. No data being available, Mr. G. C. Wood, Durham County Council Scholar of the Armstrong College, was asked to undertake an investigation of the specific electrical resistance of coal, ores, etc., and suitable samples were obtained for experiment.

The experiments have been carefully carried out by Mr. Wood, and the results obtained are of considerable practical interest.

The specific electrical resistance of coal, for the cases examined, is, in comparison with the layers above and below the coal, exceedingly high: in fact, so high that coal may be regarded as a very fair insulator. This fact, among others, is one worthy of note in connection with electrical work underground.

When the coal is damp the conductivity is practically wholly due to the water present.

Mr. Wood has recently determined the specific resistance of a Carboniferous limestone from the Barton quarries, near Darlington. This limestone has been found very suitable for use as ballast on electric railways employing a live rail. The results of tests are given at the end of the paper.

The substitution of this limestone for the coke-breeze at first used on the electric lines of the North Eastern Railway Company, has, the writer understands, practically prevented any danger to persons coming into accidental contact with the live rail, provided that there is not a simultaneous contact with the earthed running rail.

Tests have also been made of the specific resistance of Permian sandstone and Carboniferous limestone from Penrith.

There is also included a test of the specific resistance of a block of cement-concrete, composed of 2½ parts of crushed brick to 1 of Portland cement: the crushed brick comprizing equal parts of fire-brick (waste from coke-ovens) and common brick (waste).

INTRODUCTION.

The samples of coal, ores, etc., used in this investigation may be grouped as follows:—(1) Coal, and the rocks lying immediately above and below it; (2) ironstone, and the rocks lying immediately above and below it; and (3) lead-ore.

In order to obtain the electrical resistance of the coals, ores, etc., the specimens were worked into shapes with parallel faces. A paste of black-lead and water was spread evenly on the faces and dried. A copper-plate was cleaned, on this was laid a sheet of tinfoil, and on this again was placed the sample, with one of its blackened faces on the foil. On the top of the specimen was placed another sheet of tinfoil, and then another copper-plate. Thus contact could be established at the two copper-plates, and such a weight was laid on the top as from experiment showed that good contact was made.

The method employed in the measurement of the samples was one or other of the following:—(A) Wheatstone bridge; (B) high-resistance substitution; and (C) high-resistance leakage.

The specimens of coal examined were supplied from the Cowpen, Murton and St. Hilda collieries. The ironstone was supplied from Skelton Park mine. The lead-ore examined was supplied from the Greenside mine, near Penrith.

EXPERIMENTS.

(A) *Cowpen Colliery.—Mill Pit.*—(1) *Black Shale Roof.*—(*a*) The resistance (method B) of a piece, with an area of 130·4 square centimetres and a thickness of 1·2 centimetres, was 4,090 ohms; and the specific resistance was 444,000 ohms per cubic centimetre.

(*b*) The resistance of another piece, with an area of 29·8 square centimetres and a thickness of 1·12 centimetres, was 16,800 ohms; and the specific resistance was 447,000 ohms per cubic centimetre.

The mean specific resistance was 446,000 ohms per cubic centimetre.

(2) *Coal.*—The sample of steam-coal supplied from the Low Main seam was of such a shape and so easily worked, that one piece was obtained of fairly large cross-section. The resistance (method C) of a piece, with an area of 96·3 square centimetres and a thickness of 3 centimetres, was 1,120 megohms*; and the specific resistance was 36,000 megohms per cubic centimetre.

(3) *Grey Sandstone Thill.*—(*a*) The resistance (method B) of a piece, with an area of 30·2 square centimetres and a thickness of 2·8 centimetres, was 1,900 ohms, and the specific resistance was 20,500 ohms per cubic centimetre.

(*b*) The resistance of another piece, with an area of 18·4 square centimetres and a thickness of 1·2 centimetres, was 1,310 ohms; and the specific resistance was 20,100 ohms per cubic centimetre.

The mean specific resistance was 20,300 ohms per cubic centimetre.

(B) *Murton Colliery.*—(1) *Blue Shale Roof.*—(*a*) The resistance (method B) of a piece, with an area of 10 square centimetres and a thickness of 1·16 centimetres, was 50,500 ohms; and the specific resistance was 435,000 ohms per cubic centimetre.

(*b*) The resistance of another piece, with an area of 7·18 square centimetres and a thickness of 0·6 centimetre, was 34,900 ohms; and the specific resistance was 417,700 ohms per cubic centimetre.

(*c*) The resistance of a third piece, with an area of 6·67 square centimetres and a thickness of 0·8 centimetre, was 53,500 ohms; and the specific resistance was 446,000 ohms per cubic centimetre.

The mean specific resistance was 432,900 ohms per cubic centimetre.

(2) *Coal.*—The resistance (method C) of a piece from the Hutton seam, with an area of 6 square centimetres and a thickness of 0·6 centimetre, was 3,420 megohms, and in another experiment it was 3,360 megohms: the mean being 3,390 megohms; and the specific resistance was 33,900 megohms per cubic centimetre.

(3) *Blue Shale Thill.*—The resistance (method B) of a piece,

* A megohm is equal to 1,000,000 ohms.

with an area of 17·41 square centimetres and a thickness of 1·62 centimetres, was 1,210 ohms; and the specific resistance was 13,000 ohms per cubic centimetre. Owing to the nature and difficulty of working this sample into suitable pieces, it was not found possible, in view of the limited supply, to obtain more than one piece with which accurate measurements could be made.

(C) *Saint Hilda Colliery.*—The specimens from the Hutton seam comprized a sample from each of the following strata, lying in the following order:—(1) Black shale roof, (2) top panel of steam-coal, (3) bottom panel of steam-coal, (4) gas-coal, (5) coarse coal, and (6) bluish-grey posty shale.

(1) *Black Shale Roof.*—The resistance (method B) of a piece, with an area of 68 square centimetres and a thickness of 2·5 centimetres, was 12,400 ohms; and the specific resistance was 337,000 ohms per cubic centimetre.

(2) *Top Panel of Steam-coal.*—(*a*) The resistance (method C) of a piece, with an area of 24 square centimetres and a thickness of 1·2 centimetres, was 3,460 megohms; and the specific resistance was 69,200 megohms per cubic centimetre.

(*b*) The resistance of another piece, with an area of 7·8 square centimetres and a thickness of 1·1 centimetres, was 12,830 megohms; and the specific resistance was 91,000 megohms per cubic centimetre.

The mean specific resistance was 80,100 megohms per cubic centimetre.

(3) *Bottom Panel of Steam-coal.*—(*a*) This sample was very much interspersed with iron-pyrites, causing a large decrease in the resistance. The resistance (method B) of a piece, with an area of 39 square centimetres and a thickness of 1·4 centimetres, was 5 megohms; and the specific resistance was 139 megohms per cubic centimetre.

(*b*) From this specimen of coal, a piece was obtained of such a thickness, that its resistance along the bedding-planes could be obtained; but all other specimens have been measured across the bedding-planes. The resistance (method B) of a piece, with an area of 10 square centimetres and a thickness of 4 centi-

metres, was 5 megohms; and the specific resistance was 12·5 megohms per cubic centimetre. This very low specific resistance for coal was due (1) to iron-pyrites, as before stated, and (2) owing to the better continuity of the coal along the bedding-planes.

(4) *Gas-coal.*—The resistance (method C) of a piece, with an area of 19·8 square centimetres and a thickness of 1·9 centimetres, was 3,150 megohms; and the specific resistance was 33,000 megohms per cubic centimetre. The specimen of coal from this bed was of such a nature that, when broken, it was impossible to obtain more than one piece of measurable size and regular shape.

(5) *Coarse Coal.*—The resistance (method C) of a piece, with an area of 8·4 square centimetres and a thickness of 1·2 centimetres, was 485 megohms; and the specific resistance was 3,395 megohms per cubic centimetre.

(6) *Bluish-grey Posty Shale Thill.*—(*a*) The resistance (method B) of a piece, with an area of 14·5 square centimetres and a thickness of 1·1 centimetres, was 8,100 ohms; and the specific resistance was 106,800 ohms per cubic centimetre.

(*b*) The resistance of another piece, with an area of 28 square centimetres and a thickness of 1·2 centimetres, was 4,500 ohms; and the specific resistance was 105,000 ohms per cubic centimetre.

The mean specific resistance was 105,900 ohms per cubic centimetre.

(D) *Skelton Park Mine.*—The samples from the Main seam comprized:—(1) Dogger rock roof, (2) ironstone, and (3) rock thill.

(1) *Dogger Rock Roof* (a hard ferruginous post).—(*a*) The resistance (method A) of a piece, with an area of 70·5 square centimetres and a thickness of 8·8 centimetres, was 6,500 ohms; and the specific resistance was 52,100 ohms per cubic centimetre.

(*b*) The resistance (method B) of the same piece was also 6,500 ohms.

(2) *Ironstone.*—The resistance (method A) of a piece, with an area of 70·5 square centimetres and a thickness of 8·6 centimetres, was 20,430 ohms; and the specific resistance was 167,000 ohms per cubic centimetre.

(3) *Rock Thill* (ferruginous post).—The resistance (method A) of a piece, with an area of 70·5 square centimetres and a thickness of 8·4 centimetres, was 6,200 ohms; the resistance (method B) of the same piece was 6,180 ohms; and the specific resistance was 52,000 ohms per cubic centimetre.

(E) *Greenside Mine.—Lead-ore.*—(*a*) The resistance (method A) of a piece, with an area of 2·29 square centimetres and a thickness of 1·31 centimetres, was 4·21 ohms; and the specific resistance was 7·36 ohms per cubic centimetre.

(*b*) The resistance of another piece, with an area of 4·68 square centimetres and a thickness of 1·92 centimetres, was 3·02 ohms; and the specific resistance was 7·36 ohms per cubic centimetre.

(F) *Lazonby, Penrith.—Permian Sandstone.*—(*a*) The resistance (method B) of a piece, with an area of 116 square centimetres and a thickness of 3·4 centimetres, was 240,000 ohms; and the specific resistance was 8·19 megohms per cubic centimetre.

(*b*) The resistance of another piece, with an area of 52 square centimetres and a thickness of 3·4 centimetres, was 560,000 ohms; and the specific resistance was 8·56 megohms per cubic centimetre.

The mean specific resistance was 8·375 megohms per cubic centimetre.

(G) *Redhills, Penrith.—Carboniferous Limestone.*—The resistance (method B) of a piece, with an area of 52·3 square centimetres and a thickness of 2·26 centimetres, was 125,600 ohms; and the specific resistance was 2·90 megohms per cubic centimetre.

(H) *Barton Quarries.*—A sample of Carboniferous limestone from the Encrinital limestone had a specific resistance of 1,014,000 ohms per cubic centimetre.

(I).—A block of cement-concrete flooring had a specific resistance of 754,000 ohms per cubic centimetre.

Conclusions.

In the foregoing determinations direct currents with small voltages only were used; and, in order to verify the results under

different conditions, the resistances were in most cases determined:—(1) By using variable currents in a Wheatstone-bridge method, a telephone taking the place of the galvanometer, and a microphone being inserted in the battery-circuit. This method was employed in all cases where the resistance was not too large; and the results were practically identical with those obtained with the direct current.

(2) By using higher voltages: 100, 200 and 240 volts being used in this case. The resistance of any specimen, determined by this method, was found by joining it in series with a tangent galvanometer and the mains carrying the current at the required voltage. The current was measured by the galvanometer and the voltage read off by the voltmeter, and thus the resistance was directly determined. For all the specimens that could be measured in this way, it was found that there was practically no difference in the value obtained for their resistance. With a piece of coal in circuit, with 240 volts as the electromotive force employed, no deflection could be observed on the galvanometer, which was capable of detecting the current when the resistance in circuit was as high as 5 megohms: thus, by a simple direct method, it was shown that the resistance of coal was of a very high order.

TABLE I. SPECIFIC RESISTANCES OF MINERALS FOUND IN MINES.

Name of Mine.	Description of Mineral.	Specific Resistances per Cubic Centimetre.
		Ohms.
Cowpen: Mill Pit ..	Roof: black shale	446,000
Do.	Steam-coal	36,000,000,000
Do.	Thill: grey sandstone ...	20,300
Murton	Roof: soft blue shale	432,900
Do.	Coal	33,900,000,000
Do.	Thill: blue shale	13,000
St. Hilda	Roof: black shale	337,000
Do.	Steam-coal: top panel... ...	80,100,000,000
Do.	Do. bottom panel ...	*
Do.	Gas-coal	33,000,000,000
Do.	Coarse coal	3,395,000,000
Do. . . .	Thill: bluish-grey posty shale	105,900
Skelton Park ...	Roof: dogger rock ...	52,100
Do.	Ironstone	167,000
Do	Thill: bottom rock	52,000
Greenside	Lead-ore	$7\frac{1}{3}$
Penrith	Permian Sandstone	8,375,000
Do.	Carboniferous Limestone ...	2,900,000
Barton	Do. do. ...	1,014,000

* This value is omitted from the table, as the specimen contained iron-pyrites.

From an examination of the tests (Table I.), it will be seen that lead-ore is the only ore which, by practical tests based on differences in electrical resistance of large masses could, with certainty, be distinguished from the rocks surrounding it.

It may also be noticed that coal, and especially hard steam-coal, has a comparatively high electrical resistance. This important result should be borne in mind in connection with practical work.

The following values in megohms per cubic centimetre indicate the magnitudes of the specific resistance of coal and other well-known bodies: Guttapercha, 400,000,000; arc-light carbon, 0·000,000,004; and coal, say, 40,000. Coal has, consequently, ten million million times greater resistance than arc-light carbon and ten thousand times less resistance than guttapercha of the same dimensions.

APPENDIX A.—Section of Strata adjacent to the Low Main Coal-seam, Mill Pit, Cowpen Colliery, Northumberland.

No.	Description of Strata	Ft.	Ins.	Thickness of Strata. Ft.	Ins.	Ft.	Ins.
1	Post girdles			0	7		
2	Grey metal, with iron-stone-girdles			5	10		
3	COAL			0	10		
4	Thill-stone			1	10		
5	Grey metal, with post-girdles			15	4		
6	Grey post			23	6		
7	Grey metal			2	2		
8	Black shale			0	5		
				——		50	6
	Low Main Coal-seam:						
9	COAL, grey	0	2				
10	COAL, steam-coal	4	8	4	10		
				——		4	10
11	Grey sandstone			8	8		
12	COAL			0	1		
13	Thill-stone			3	6		
14	Grey metal			2	6		
15	Post girdle			2	3		
16	Grey metal			14	8		
17	Black stone			3	4		
18	Grey metal and black stone, with ironstone-girdles			5	7		
	Plessey Coal-seam:						
19	COAL ...	0	5				
20	COAL, with grey bands ..	1	1¼				
21	Stone and coarse *coal* ...	0	5½				
22	COAL ...	1	6				
		——		3	6		
23	Thill-stone ...			1	4		
24	Post, into ..			3	2		
				——		48	7

APPENDIX B.—Section of Strata adjacent to the Hutton Coal-seam, Murton Colliery, Durham.

No.	Description of Strata.	Ft.	Ins.	Thickness of Strata. Ft.	Ins.	Ft.	Ins.
1	Black stone			11	4		
2	COAL			0	10		
3	Grey metal			4	0		
4	Post, mixed with whin			19	0		
5	Grey metal, with post-girdles			11	9		
6	Blue shale			0	7		
				——		47	6
	Hutton Seam:						
7	COAL ...	5	0				
8	Band	1	0				
9	COAL ...	1	2				
10	Black stone ...	0	4				
		——		7	6		
				——		7	6

APPENDIX B.—Section of Strata adjacent to the Hutton Coal-seam, Murton Colliery, Durham.—*Continued.*

No.	Description of Strata.	Thickness of Strata. Ft.	Ins.	Ft.	Ins.
11	Blue shale, with post-girdles ...	12	9		
12	Blue metal, mixed with ironstone	14	5		
13	Black metal	0	8		
14	COAL	0	7		
15	Dark-colored thill ...	3	0		
16	Grey metal	13	0		
				44	5

APPENDIX C.—Section of Strata adjacent to the Hutton Coal-seam, St. Hilda Colliery, Durham.

No	Description of Strata.	Ft.	Ins.	Thickness of Strata. Ft.	Ins.	Ft.	Ins.
	Five-Quarter Seam:						
1	COAL ..	0	6				
2	Black band ...	0	2				
3	COAL	1	8				
4	COAL, splint	1	0				
5	COAL ...	1	1				
				4	5		
6	Thill-stone			1	11		
7	Grey metal			7	4		
8	White post-girdle ...			0	10		
9	Grey metal, mixed with post			0	11		
10	White post ...			15	8		
11	White post-girdles, with metal partings ...			6	0		
12	Grey metal			6	7		
13	COAL, splint			0	6		
14	Black shale			1	10		
						46	0
	Hutton Seam:	Ft.	Ins.				
15	COAL, steam-coal, top panel ..	2	0				
16	Black stone ...	0	4				
17	COAL, steam-coal, bottom panel	0	11				
18	COAL, splint, coarse coal ...	0	1				
19	COAL, gas-coal	3	6				
				6	10		
						6	10
20	Bluish grey posty shale			8	0		
21	Grey metal, with scares of *coal*			19	9		
22	Post, with scares of metal			4	11		
23	Grey metal, with scares of post			5	2		
24	Grey post-girdle ..			1	11		
25	Grey metal, with scares of post			6	8		
26	White post			8	4		
27	Grey metal, with scares of post			13	10		
						68	7

APPENDIX D.—Section of Strata adjacent to the Main Ironstone-seam, Skelton Park Mine, Cleveland, Yorkshire.

No.	Description of Strata.	Thickness of Strata. Ft.	Ins.	Ft.	Ins.
1	Jet shale	26	10		
2	Dark-grey shale ...	25	6		
3	Light-grey shale ...	2	0		
4	Dark-grey shale ...	5	10		
5	Dogger-rock	2	6		
				62	8
	Main Seam:				
6	Ironstone	10	0		
				10	0
7	Black hard or rock thill	4	0		
8	Shales, with ironstone-bands and doggers ...	7	6		
	Bottom Seam:				
9	Ironstone	3	6		
10	Shales, etc.	20	0		
				35	0

Mr. P. Kirkup wrote that a workman had received a shock, when standing on a cement-floor, due to an improperly insulated switch-gear at an underground haulage-motor, at a pressure of only 250 volts.

Mr. Henry Lawrence stated that the paper endorsed the use of the limestone-ballast which had been recently adopted by the North-eastern Railway Company for use on their electric lines.

Mr. J. B. Simpson asked whether the action of the engineers of the North-eastern Railway Company had been due to the results of the experiments made by the writer.

The President (Mr. T. W. Benson) said that the amount of resistance of the ballast recorded in the paper seemed to warrant its use on the electric lines.

Mr. M. Walton Brown said that the high electric resistance of the Barton limestone was discovered a few months ago, some time after Prof. Stroud had begun his experiments, but independently. The results of the experiments described in the paper shewed that, although the Barton limestone had a resistance of over 1,000,000 ohms per cubic centimetre, any coal would form a better material for ballasting electric lines, as the lowest resistance of that mineral was about 3,400,000,000 ohms. Coal had consequently, say, 3,400 times greater resistance than Barton limestone of the same dimensions.

Mr. J. B. Simpson asked whether coke had a high resistance.

Mr. M. Walton Brown said that coke-ballast had a very low electric resistance, but it had not been measured by Mr. Wood. These experiments had considerable bearing upon the method arranged by Messrs. Leo Daft and Alfred Williams for discovering lodes of ore, and the results shewed that if lead-ore, which had a low specific resistance, could be discovered with their apparatus, it was not likely that the occurrence of the ironstone tested, which had a specific resistance of 167,000 ohms per cubic centimetre, would be indicated.

Mr. George C. Wood, with regard to the suggestion of the substitution of coal for Barton limestone, wrote that as a practical insulator, in this connection, coal would not answer very on account of its softness, etc., and as it did not take up wet readily it would take a long time to dry. He imagined that coke would be of the same order of resistance as arc-light carbon.

The PRESIDENT (Mr. T. W. Benson) said that the members were greatly indebted to Prof. H. Stroud and Mr. G. C. Wood for undertaking the experiments recorded in the paper. The results were highly technical and exceedingly interesting. He had pleasure in moving a vote of thanks to them for their paper, which contained the results of a large part of a year's work.

Mr. J. B. SIMPSON, in seconding the resolution, said that the paper was a valuable contribution, and raised questions which, he was not aware, had hitherto been raised by anyone. There could be no doubt that it would be productive of practical results, and thus attain one of the objects of the Institute.

The motion was cordially approved.

Mr. WILLIAM FRYAR's paper on "A Mechanical Coal-cutter in Queensland" was read as follows:—

A MECHANICAL COAL-CUTTER IN QUEENSLAND.

By WILLIAM FRYAR.

The first installation of a mechanical coal-cutter has been made by Messrs. McQueen & Company, at the Boxflat colliery, Bundamba. It should be understood that everything in Queensland is done on a small scale, the total annual output of coal in the State barely exceeding 500,000 tons. It is therefore considered, and is, an unprecedented step to find an installation, such as that now under consideration, become an accomplished fact.

The seam in which the installation has been made is not unsuitable for that method of working. It varies from 5 feet 8 inches to 6 feet in height: a coarse band, running in the middle, includes stone and coal, from 8 to 10 inches thick. The roof is of coarse coal, and fairly strong, and the floor is hard. A slightly objectionable feature is the gradient at which the seam is inclined: from 1 in 5 to 1 in 3½. This, however, is not higher than is usual in the district: it is seldom less, but on approaching to a considerable dislocation it is generally much higher.

The rooms, usually 24 feet wide, are, however, driven about halfway between the rise and the strike of the seam; and since the introduction of the mechanical coal-cutter they have been driven 42 feet wide.

The machine used is of the Goodman chain-cutter type, and appears to be very suitable for the duty expected of it. The weight is about 1 ton 3 cwts. (Fig. 1). The Goodman coal-cutter consists of the motor, the bed-frame and the cutter-frame. The compound-wound motor, placed above the bed-frame, runs at a moderate speed with light cuts, and slows down with heavy cuts. One peculiarity of the coal is its friability, and it therefore does not require any very great power to drive the coal-cutting apparatus. The cutter-frame carries the chain, fitted with 39

teeth or cutters spaced about 6 inches apart, placed at various angles, and making a cut 4 inches high and 44 inches wide. The teeth appear to brush the débris well out towards the front of the cut, whence it is shovelled away by an attendant. The machine is secured in front by a support against the face of the coal, rigidly fixed by a screw-jack, whilst a similar vertical screw-jack, from floor to roof, secures it at the outer end.

Fig. 1.—Goodman Coal-cutter and Westinghouse Vertical Compound Engine.

After a cut has been made, usually in about 3 minutes, the mechanism automatically reverses the direction of travel of the motor, and it is speedily brought back to a position suitable for commencing the next cut. At this point, however, there is something to be desired, as the machine is moved upwards by a couple of crow-bars and manual power; and this is required to be done repeatedly in the transit across the room. About 3 minutes are occupied in placing the machine in position for another cut. A cut 5 feet deep and 51 feet wide has been made in 2½ hours. The cut having been completed, the removal of

the machine down hill is not a difficult matter, and having been placed in line with the tram-road, the carriage is brought up against it and tipped up until the nose is placed under the motor. Then a capstan is operated at the outer end, and the machine is drawn on to the carriage, which is moved away by the power of the motor and taken to the next adjoining or such other room as is available for its use.

There is a sufficient length of loose cable available, to permit of its removal from one room to another without interfering with any connections, or removing the cable attached to the motor.

The surface-plant comprizes a Westinghouse vertical compound engine (running at 350 revolutions per minute) of 50 horsepower (Fig. 1), which drives a compound-wound direct-current generator of 30 kilowatts. The pressure may be run up to 300 volts, but 250 volts is generally used, and supplies a current of 120 ampères or 40 horsepower.

The electricity is conveyed to the points of duty by a bitumen-covered cable, 2¼ inches in diameter, down the shaft, about 400 feet deep. A considerable proportion of the power is utilized in working a newly installed three-throw ram-pump at the shaft-bottom, and in lighting some of the travelling-roads in the mine.

It may be considered premature to speak of the relative cost of hand- and machine-cutting, although when one sees them at work it scarcely seems possible that, even under the disadvantage of inexperience with the mechanical cutter, it cannot do the work at a less cost than it can be done by hand. Indeed, the proprietors are so satisfied on this point that they have arranged for a second machine: the motive power, the cable, and other appliances being sufficient for the additional duty. The saving of breakage of the coal is most important from a pecuniary point of view; it is well known that miners are not very particular about the height of the holing or kirving, but any unnecessary breakage from this cause is entirely avoided by the machine.

The superiority of the three-throw ram-pump over that previously in use and the facility with which the power is transmitted have enabled the owners to dispense with the use of one of the boilers at the surface. The advantage of a good light at the shaft-

bottom, as well as at the foot and the top of the self-acting inclined planes and on horse-roads, is also well known, and tends largely to the prevention of accident at these points.

A small ventilating fan, capable of producing a current of 28,000 feet per minute, will be driven by the electric plant: this, however, is comparatively unimportant, as the outlet is placed on the outcrop of the seam, at a much higher level than the top of the winding and downcast shaft, thus ensuring ascensional ventilation throughout the mine.

It is a matter of the utmost importance to colliery-owners in Queensland that they should adopt the latest improvements, the best labour-saving appliances, and the most effective means of safely conducting mining operations, as the competition is very keen, owing to the proximity of the larger coal-fields of New South Wales; the labour-conditions are not always satisfactory, and the workmen are not, in all cases, trained pitmen from boyhood.

Mr. Robert Hunter (H.M. Inspector of Mines, Gympie, Queensland) wrote that considerable interest attached to the installation of a mechanical coal-cutter at the Boxflat colliery, not from any novelty in the design of the Goodman machine, which is of a type largely used in the United States of America, but from the fact that its introduction marked a new departure in the Queensland coal-mining industry. Although electricity is largely used for lighting and power-purposes in metalliferous mines, this plant is the first installation in Queensland of an electric lighting and power-plant in a coal-mine.

The results obtained so far appear to have amply justified Messrs. McQueen & Company's action in undertaking, what was thought by some to be, a doubtful experiment. Owing to the steepness of the gradient in some parts of the mine, difficulty was at first experienced in moving the machine into position for each cut, and in keeping it there until the cut was completed. This difficulty has now been very simply overcome. A post is erected on the top-side of the room. Then a small horizontal ratchet-capstan is hooked to the side of the machine and the loose end of the rope on the capstan is made fast to the post, after which, by means of the ratchet, the machine is easily and quickly removed into the desired position.

It was to be regretted that in Queensland sufficient skill in getting large coal was not usually shown, as, owing to the friability of the mineral, this was a point requiring great attention. The use of the coal-cutting machine appeared to have resulted in the placing on the market of the coal in a much cleaner condition, and not so badly broken up as was formerly the case. A second machine had been procured and was in use, so that practically all the coal was cut by the two machines. After a machine had completed the holing, the ends were cut loose and generally the lower part of the seam came easily away from the stone, referred to by Mr. Fryar. After the lower part of the seam and the stone had been removed, the upper portion was generally broken down easily by wedges.

The PRESIDENT (Mr. T. W. Benson) said that it was undoubtedly interesting to hear of the application of coal-cutting machines in the Colonies. It was doubtful whether, in this country, they would have concerned themselves with the use of coal-cutters, if they had seams, 6 feet thick, to work, as in the case described. The scarcity of trained workmen in Queensland, as well as the high rate of wages which prevailed, had most probably led to the introduction of the machines. He had pleasure in proposing a vote of thanks to Mr. Fryar for his interesting paper.

Mr. J. B. SIMPSON seconded the vote of thanks, which was cordially adopted.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING.

HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE, OCTOBER 14TH, 1905.

MR. T. W. BENSON, PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, and reported the proceedings of the Council at their meetings on August 19th, September 30th and that day, and of the Council of The Institution of Mining Engineers.

The following gentlemen were elected, having been previously nominated:—

HONORARY MEMBER—

MR. WILLIAM WALKER, H.M. Inspector of Mines, Doncaster.

MEMBERS—

MR. CHARLES BERTRAM, Electrical Engineer, 4, St. Nicholas' Buildings, Newcastle-upon-Tyne.

MR. WILLIAM E. DONALD, Mining Engineer, Rhodesia Broken Hill, North Rhodesia, South Africa.

MR. JAMES FLETCHER, Assistant Mining Engineer and Mine Surveyor, Granity, *via* Westport, New Zealand.

MR. EDWARD LYALL, Civil and Mining Engineer, 4, Vane Terrace, Darlington.

MR. DAVIDGE PAGE, Engineer, Hotel Russell, Russell Square, London, W.C.

MR. WILLIAM SHAW-DUNCAN, Civil and Mining Engineer, San Lorenzo de la Muga, por Figueras, Provincia de Gerona, Spain.

MR. CHARLES MACLAGAN WEDDERBURN, Mining Engineer, 8, East Fettes Avenue, Edinburgh.

ASSOCIATE MEMBERS—

MR. WILLIAM LATIMER, Hollyhurst, Winlaton, Blaydon-upon-Tyne, R.S.O., County Durham.

MR. RICHARD JOHN MATCHETT, 12, Hatton Terrace, Ilford, Essex.

DISCUSSION OF MESSRS. WILLIAM CUTHBERT BLACKETT AND ROBERT GALEN WARE'S PAPER ON "THE CONVEYOR-SYSTEM FOR FILLING AT THE COAL-FACE, AS PRACTISED IN GREAT BRITAIN AND AMERICA."*

Mr. J. B. Atkinson (H.M. Inspector of Mines) said that, in a Presidential Address delivered to the members of the Mining Institute of Scotland, in 1891, he had referred to the subject as follows:—

> I think some improvement might be effected in the carriage of coal along the faces of thin seams worked longwall, so as to save the brushing of so many roads. It is usual in such cases to have a road for every 10 or 15 yards of face, the life of most of these roads is short, while the brushing of them costs perhaps 6s. per yard. Slipes or small hutches, with or without wheels and holding 2 or 3 cwts. of coal, are used in many cases to convey the coal along the face to the road-head. If some ready plan could be devised to carry the coal, say 50 yards, in a height of from 2 feet downward, the cost of the brushing of many roads would be saved.†

He (Mr. Atkinson) was glad to see that in the hands of Mr. W. C. Blackett and others, satisfactory systems had been evolved. The new system was accompanied with some appearance of danger, owing to some of the men working so far from a gateway: this pointed to the necessity of careful timbering of the face, and he had no doubt that this would be done. He was inclined to think that the conveyor-system would probably reduce the general liability to falls, because it was not necessary, with this method of wide-spaced gateways, to break so often into the roof. When a thick canch was shot in, at intervals of 30 feet or thereabouts, falls were much more likely to occur, where the shooting was going on and also along the face, than where the face had an unbroken length of 150 or 300 feet.

The President (Mr. T. W. Benson) asked whether, as the result of the operations of the coal-conveyor, there was any difficulty with regard to the support of the surface; whether the old ordinary system of working longwall afforded a better support for the surface; and whether the extra-deep gateway, required when working with the conveyor-system, made any difference in this respect. Perhaps in the mines where conveyors were work-

* *Trans. Inst. M. E.*, 1905, vol. xxix., page 449.

† *Trans. M. I. Scotland*, 1891, vol. xiii., page 17.

ing, no difficulties had occurred with respect to the support of the surface, but it had an important bearing, nowadays, in some districts. It was satisfactory to find that Mr. J. B. Atkinson's forecast of 12 years ago had now been put into practical operation. He was inclined to agree with that gentleman in his remarks as to safety, and he thought that the difference between firing heavy shots in gateways, 450 feet apart, and shooting a thick canch in gateways only 30 feet apart, must be very great; and the roof must be much more shaken in the proximity of the latter.

Mr. J. H. Merivale remarked that the difficulty of moving the conveyor forward, in the entirety of its length of 200 or 300 feet, was considerable, and if the joints could be readily broken, the conveyor could be easily moved forward in lengths of 20 feet or more, and as quickly put together again. It was probably impracticable to discover some means of dealing with "troubles," which militated greatly against the use of coal-cutters and conveyors. A face would be started after exploration, but after a few months, the coal-cutter and the conveyor were laid idle until the workings passed through a fault by hand-labour, very considerable expense being involved.

Mr. W. C. Blackett agreed with Mr. Atkinson and also thought there could be no doubt that the use of his (Mr. Blackett's) conveyors in a longwall-face must necessarily result in greater safety, because they could not be used unless some stringent form of systematic timbering was also adopted. A few years ago, it was pointed out that systematic timbering was much better done on the Continent than in this country, and the methods were described as a pattern to be followed. If the Home Secretary was then right in recommending the adoption of systematic timbering, and the views expressed were sound, then the conveyor-system, as it necessitated such systematic timbering, for that reason alone must be safer. Admirable systems of timbering had been adopted at Ashington, Consett, Kimblesworth and other collieries, where the conveyor-system had been introduced. His (Mr. Blackett's) system was employed in Wales, in the Midlands, in Northumberland and Durham, and in Scotland, where the conditions were of course widely different, and it was impossible to generalize as to the effect on the surface.

If a daily rapid advance in a straight line would have any particular effect on the surface, then the results would have to be observed; but whether it would be different, because of that, he would not like to say. The conveyor, as sent out now and as explained in his (Mr. Blackett's) paper, was arranged so that each joint could be broken at intervals of 6 feet, without undoing a single nut, except one on the conveyor-chain. In practice, it was found that it was much easier, when the men were used to it, to move the conveyor forward as a whole, but necessarily each seam would require special consideration to suit its own particular conditions. One great advantage, that had not been specially pointed out, was the greatly increased quantity of coal which could daily be got from a very much smaller area of mining operations than was at present possible by any other known method.

DISCUSSION OF MR. J. W. BATEY'S PAPER ON "THE MICKLEY CONVEYOR."*

Mr. Edward Watson (Cannock) wrote that he hoped to adopt a somewhat similar conveyor, in Staffordshire, in a seam 3 feet thick. It occurred to him that a sort of windlass-and-pawl arrangement, at one end of the conveyor, whereby the rope could be lengthened or shortened, and the return-wheel advanced by the loader, each day, would be an advantage, especially in the Cannock district.

Mr. James Wilson (Edmondsley) wrote that the Mickley conveyor had been tried at Edmondsley colliery for conveying the coals along a longwall-face, but the use had been temporarily abandoned owing to the face becoming seriously broken up by five hitches, with throws of 3 feet, 2½ feet, 2 feet, 1 foot and 5 inches respectively. The occurrence of these hitches made it practically impossible to control the face and to use the conveyor successfully.

The conveyor consisted of a wooden kibble (6 feet long, 3¼ feet wide, and 14 inches high on the rails), fitted, in the bottom, with two sliding-doors, actuated from the ends. The conveyor

* *Trans. Inst. M. E.*, 1905, vol. xxix., page 268.

was run along the face by an endless wire-rope, passed one-and-a-half times round the driving-wheel, which was supported upon the standard or frame of an ordinary stoneman's drilling machine, and round a return-wheel about 180 feet away.

This method of conveying the coals is much slower than the Blackett conveyor, but the appliance is very much easier to move forward and takes up much less room; and a lad can work the conveyor on a face, 180 feet long, with an output of about 50 tons a day. If a big fall happens, the loss is not very great, as every part can be made at a colliery, at a slight cost.

He (Mr. Wilson) suggested that two Mickley conveyors, in all 450 feet long, delivering coal into tubs standing in one gateway, might be conveniently worked by one endless-rope driven by a small motor, placed between the conveyors.

Mr. Hiram Baddiley (Wakefield) wrote that it was altogether unnecessary for him to dwell to any extent on the paper, as the very fact of the conveyors being repeatedly introduced by persons who had actually tried and operated them, confirmed their success underground, both from a financial point of view and also from their tendency to reduce the number of accidents. He had a mechanical coal-conveyor working in a similar seam, and each man, under these conditions, averaged about 10 tons per shift, filling from coal under-cut by machinery; consequently, the working results did not strike him with the same surprise as perhaps they might others, who had not gone quite so fully into the practical and possible results of using such machinery underground.

Whatever the class of conveyor, whether worked mechanically or by hand-labour, the aims were the same, namely:—(1) To reduce the winning price of coal; (2) to get more coal, from a given area, in a certain time; (3) to minimize the number of accidents; (4) to obtain a greater percentage of round coal, etc. These objects are attained, as will be apparent, by reducing the number of gateroads leading to the face, and these are often a source of annoyance and expense. Another great feature is that the employment of boys belowground at the working-faces is in this case almost entirely abolished.

It appeared to him (Mr. Baddiley) that the Mickley conveyor had one great disadvantage, because, practically speaking, only

one tub, or a box of equal capacity, could be run backward and forward along the face for each tub of coal sent from the conveyor-face to the main-gateway. Moreover, only two men could be filling coal at the same time. This, to his mind, was a very slow process, and capable of great alteration as regards economy. Without going into any actual figures, it must take a considerable time by this method to fill the coal from a face 156 feet long. However, some of the results previously mentioned had been attained; the working cost had been reduced and the output per man had been largely increased, which was the principal object of introducing this class of machine. In conclusion, though he (Mr. Baddiley) did not know the exact circumstances at Prudhoe colliery, he was only sorry that Mr. Bates had not, at present, the facilities for introducing modern machinery to be driven mechanically, as he felt confident that, although Mr. Bates' efforts had up to the present time been successful, they would under such conditions meet with the still greater success which they so richly deserved.

DISCUSSION OF MR. J. H. PIFFAUT'S PAPER ON "THE USE OF CEMENT-CONCRETE IN THE WORKING OF THICK COAL-SEAMS."*

Mr. Richard Kirkby (Leven, Fifeshire) wrote that, if the method described by Mr. Piffaut would work out as cheaply in Britain as in France, there were many collieries working thick coal-seams (by longwall methods) whose owners would be glad to commence at once with concrete-layers between the different leaves of working. He (Mr. Kirkby) was afraid, however, that the method could not be carried out so cheaply in Scotland as at the Perrecy collieries. He thought that cement-concrete, made from one part of cement to two parts of sand and four parts of stone, was cheaply made at 15s. per cubic yard. Supposing that it were made of one part of cement to ten parts of stone in place of one to six as above described, the cost would be 12s. per cubic yard, with cement at £1 12s. per ton. Again, best blue lime (Fifeshire) cost 18s. per ton, and concrete made with one part of such lime to six parts of sand and stone would cost 11s. per cubic yard.

* *Trans. Inst. M. E.*, 1905, vol. xxix., page 274.

In a seam, 18 feet thick, worked in three leaves or lifts, two layers of concrete would be used, and ½ cubic yard of concrete would be required per superficial yard of the seam. A superficial yard produced about 5½ tons of coal; and the cost of cement-concrete would be therefore 1s. per ton of coal. The preceding costs were for cement-concrete made with cheap surface-labour; but, in the pit, the laying of the cement-concrete would be done by underground labour, costing double the surface-rates, and, consequently, an extra cost of 3d. per ton would probably be incurred.

Another point should also be considered, namely, the loss of output while the paving was being laid and the cement-concrete was setting. This delay would, of course, add a little to the cost per ton.

He (Mr. Kirkby) asked whether there were any bands or partings of stone in the seam, and also as to the extent to which the waste or gob was packed above the cement-concrete. It would also be interesting to know the reasons for working the seam, in leaves, downward, instead of upward from the bottom. Probably there was less chance of the coal being crushed and causing spontaneous fires by the downward method of working.

Mr. J. P. Kirkup (Burnhope) wrote that, from considerable experience in the working of coal underlying an old goaf, and only separated by a thin parting of fire-clay, he considered that the use of an artificial parting of cement-concrete would be of service in forming a false roof to the underlying section of the seam; but, owing to the very considerable expense of the method, its use would, of necessity, be confined to the working of very thick seams of coal. The heaving of the goafed area would lead one to expect that the layer of cement-concrete would, at times, be broken and twisted into anything but the horizontal layer in which it was laid; and this would cause difficulty in timbering underneath it, although, from his (Mr. Kirkup's) experience, this would be as nothing compared to working the coal without the artificial roof. Cheaper materials were evidently available in France than in this country as he (Mr. Kirkup) thought that cement-concrete, 9 inches thick, would cost 8s. or 9s. per square yard in this country. Could Mr. Piffaut indicate the economy of timber effected in removing the lower portion of the seam, if any experience had been gained in that direction?

DISCUSSION OF MR. DONALD M. D. STUART'S PAPER ON "THE DEVELOPMENT OF EXPLOSIVES FOR COAL-MINES."*

Mr. H. Hall (H.M. Inspector of Mines) wrote that he had read Mr. Donald Stuart's paper on the development of explosives for coal-mines with considerable interest, but he was afraid that the ingenious theories and deductions advanced entirely broke down when the actual facts were considered. For many years previous to the issue of the Explosives in Mines Order of December 19th, 1896, there had been a growing outcry against blasting with gunpowder; frequent disastrous mine-explosions were traced to the firing of gunpowder-shots, and no doubt action would have been taken earlier, had it not been for the lack of a safer explosive. However, matters went from bad to worse, but, fortunately, about this time, a different class of explosive (almost flameless) was invented, and the opportunity was at once taken to forbid the use of gunpowder in certain classes of mines, and, as events had proved, with signal success. Fatal explosions of fire-damp and coal-dust had been reduced, both in number and in destructiveness, to a most remarkable degree. Taking the three decades, beginning in 1875 and ending in 1904 (a period during which much deeper mines had been opened, and the number of persons employed underground had increased from 427,017 to 681,683 and the output of coal from 133 million to 232 million tons) the average annual loss from explosions in the first decade was 256 lives; in the second decade, 174 lives; and in the third decade, 60 lives: the last decade coinciding with the use of safety-explosives on a large scale.

Although Mr. Stuart stated that there were the same number of fatal explosions of fire-damp due to shot-firing in the six years under the Explosive Order, as in the six years antecedent, and that there were actually more non-fatal explosions in the former period,† he did not state how many of these explosions were the result of the continued use of gunpowder in certain of the mines-inspection districts.

* *Trans. Inst. M. E.*, 1905, vol. xxix., page 299.

† *Ibid.*, page 311.

The suggestion* made by Mr. Stuart that the test-chamber at Woolwich would be fatal to some of the explosives now on the Permitted List, if the gun were so placed that the gases from the shot might strike against the roof or floor of the chamber, was worth a trial.

He (Mr. Hall) submitted that Mr. Stuart's explanation of the great reduction of the death-rate being due to "arrest of propagation, that is to say, by conditions distinct from the shot, and wholly independent of the explosive,"† was erroneous. "Propagation" could only be hindered by more copious watering and removal of the dust from the roads, and, in his experience, less attention was paid to these precautions now than was the case during the period prior to the enforcement of permitted explosives. It was a fact, as Mr. Stuart pointed out, that many of the explosives on the Permitted List might ignite, and had ignited fire-damp exuding into the drill-hole and in contact with the charge, without any intervention of stemming, but such conditions were somewhat rare. On the other hand, gunpowder and similar flaming explosives were almost certain to ignite any fire-damp lurking about the roof near the shot, and if a blown-out shot of gunpowder were to occur, where dry coal-dust was present, the probable result was awful to contemplate.

Mr. Robert McLaren (H.M. Inspector of Mines) wrote that Mr. Stuart was at great pains to show that, while explosions of gas and coal-dust had resulted from the flame of the explosive used, they had not been altogether from gunpowder. Some of the higher explosives had emitted, and probably did emit flame, but the broad fact remained that none of the higher explosives emitted flame to the same extent as gunpowder. He would be a bold man who would affirm that flame could not be produced, when a shot was fired by an explosive, however flameless of itself, as the detonator which would give flame had to be taken into consideration; and, until the composition of the explosive was such that the resultant gases, due to the chemical action on ignition, could extinguish flame or sparks as emitted, absolute flamelessness from explosion of shots could not be looked for.

A quotation was made by Mr. Stuart that "the lowest grade

* *Trans. Inst. M. E.*, 1905, vol. xxix., page 321.

† *Ibid.*, page 313.

of common blasting gunpowder can frequently be fired without igniting the gas, if it is stemmed well with puddled wet clay of a good stiff consistency,"* and he further stated that "such wet stiff clay is ordinarily used in practical mining."† He (Mr. McLaren) must take exception to this statement, as such was not the case: if Mr. Stuart had stated that damp clay was ordinarily used, he would have been nearer the mark. It might interest him to know that in the East Scotland mines-inspection district about 2,000,000 shots were fired per annum in the shale-mines; and the shale-borings, used for stemming, were not even damped in some cases.

In his (Mr. Stuart's) anxiety to make the position of the explosives of the gunpowder-class satisfactory to owners and managers, he quoted some remarks made on the tests of bobbinite by Captain J. H. Thomson. It was stated that this explosive gave off sparks and glow, and apparently despite this fact was not an unsafe explosive.‡ In this connection it certainly would be a most unwise thing for any man, who had knowledge of gas and coal-dust, to allow a shot to be fired by any explosive whence sparks and glow resulted, in an atmosphere of an explosive nature, nor did he (Mr. McLaren) think that Mr. Stuart would care to be present under such circumstances.

It was further stated that "every shot that has ignited gas or coal-dust in a mine has created the potential start of an explosion; and the result, whether fatal or non-fatal, depends upon conditions entirely distinct from the shot."§ The reasoning in this last clause was far from convincing: granted that the result depended upon conditions entirely distinct from the shot, it surely followed that, if there were no shot to alter these conditions, no harm could happen, so long as the conditions were undisturbed; but, having all the elements necessary, fire-damp, air and coal-dust, it only required pressure and flame (such as a shot could produce) to set up new conditions, and an explosion occurred. The initial cause, therefore, of the explosion was the shot, which altered the conditions.

* *Twenty-fourth Annual Report of H.M. Inspectors of Explosives; being their Annual Report for the Year 1899*, page 119.

† *Trans. Inst. M. E.*, 1905, vol. xxix., page 305.

‡ *Memorandum on the Testing of Explosives for Coal-mines, and on the Behaviour of the Explosive Bobbinite*, by Captain J. H. Thomson, H.M. Chief Inspector of Explosives, March 7th, 1904, page 2.

§ *Trans. Inst. M. E.*, 1905, vol. xxix., page 311.

It appeared that H.M. inspectors of mines were at fault in attempting to administer the Explosive Order: it surely was a commendable thing on their part to try and prevent explosions causing loss of life, by asking the owners to use a safer explosive for blasting in mines, in which the conditions called for such; and the owners were on the whole as anxious as H.M. inspectors of mines to try, if possible, to reduce the risk of explosions, and voluntarily introduced permitted explosives. In many mines, to which the Explosives Order did not apply, permitted explosives were being used in preference to gunpowder, on the ground that the former worked better in some kinds of strata.

Objection must be taken to the statement that the policy of H.M. inspectors of mines was to abolish the use of gunpowder in mines, as no such thing was ever contemplated, but when the conditions of a mine rendered its use dangerous, gunpowder was certainly prohibited. The Explosives Committee, responsible for drawing up the Permitted List, were taken to task, because their tests in some cases did not turn out exactly as expected. Mr. Stuart was scarcely fair to them, as he must be aware that even with the best management it was not possible to get every condition that might be found in a mine; a condition might suddenly arise, which was not dreamt of, and which no one could possibly control. The Explosives Committee must get the credit of experimenting, on the whole successfully, in conditions as near as possible to those existing in a mine under ordinary circumstances, and they proved one thing, at least, namely, that gunpowder was not a safe explosive for use in mines where gas or coal-dust existed.

DISCUSSION OF MR. JAMES ASHWORTH'S "OBSERVATIONS ON WATER-SPRAYED OR DAMPED AIR IN COAL-MINES."*

Mr. J. Cresswell-Roscamp (Low Fell) wrote that Mr. Ashworth's paper was a collection of expert opinions and conclusions as to the inflammability of coal-dust; and having proved, by quotations, conclusively that the explosive nature of coal-dust was due to its extremely fine and dry condition, he repudiated

* *Trans. Inst. M. E.*, 1905, vol. xxix., page 11.

the whole argument by stating that "it is useless, therefore, to depend on water-sprays for restraining the extension of an explosion after it has once been initiated."* It was the more difficult to understand why Mr. Ashworth came to this conclusion; as he did so immediately after referring to the Tylorstown and other explosions. Mr. Robson in his report on the Universal explosion says "in my opinion, this [prevention of accumulation of coal-dust] can only be done by constant and efficient watering."† The fact that watering may not always have been efficient in preventing the spread of an explosion is no reason why it should be condemned as useless.

The prevention of accumulations of thin layers of fine coal-dust on the supporting timber and sides of the roadways is impossible, and moreover its inflammability is increased by the action in deep mines of the high temperature of the circulating atmosphere. Some means must, therefore, be adopted so to treat these accumulations as to make the dust a non-supporter of rapid combustion. All recent explosions prove that the greatest danger is provided by the finest dust on the timber and sides, as shewn by their charred condition afterwards, and the coarser dust on the floor may be disregarded. It appears, therefore, conclusive that the dangerous dust is that which is carried about by the circulating air-current and conveyed by it into places, inaccessible save by its assistance, and also by it deposited on the sides of the roadways. The most efficient method of treating dry inflammable coal-dust must, therefore, be by the aid of the very force of nature, which has not only deposited the dust where it is most likely to cause an explosion, but to whose agency its explosive nature is due. This, it is evident, can only be attained by lowering the temperature of the circulating air and by adding moisture to it, both of which conditions will in turn be imparted by it to the coal-dust. One means by which this may be done, and in his (Mr. Roscamp's) opinion the most efficient, is by using a fine spray of water emitted from a travelling tub attached to the in-going and out-coming set of

* *Trans. Inst. M. E.*, 1905, vol. xxix., page 20.

† "Report," by Mr. J. T. Robson, *Reports to H.M. Secretary of State for the Home Department on the Circumstances attending an Explosion which occurred at the Universal Colliery, Glamorganshire, on May 24th, 1901*, by Prof. W. Galloway, Mr. S. T. Evans and Mr. J. T. Robson, 1902, page 32.

tubs.* The constant use of such a spray, as most will admit, will remove, at least, the most favourable condition for the formation of highly inflammable coal-dust, namely, a hot dry atmosphere. Further, this condition will be attained without any injury to the roof, floor or sides, because, by the use of such a spray, they will not be deluged with water, which happens with most applications of water in mines. The use of a water-spray should not be put down as ineffective, simply because at first no visible trace of dampness is present; but, at the same time, an instant change will be observed by the use of wet-bulb and dry-bulb thermometers before and after the application.

Mr. James Ashworth wrote that Mr. Roscamp was in error, in saying that he had proved that the explosive nature of coal-dust was due to its "dry" condition, because he considered that any percentage of dampness which Mr. Roscamp or any one else could put into the air of a coal-mine added to its explosive condition; and, on the other hand, the drier the air the safer was the mine. It had been proved that, until the dampness in the air exceeded 25 per cent. of the weight of the air, it had no retarding influence on the flame of an explosion. As to cooling the air with water, this also had proved to be an impossibility in practice. Messrs. W. N. Atkinson, H. Bramall, John Gerrard, H. Hall, and others† before the Royal Commission on Coal-supplies, showed that dry air was the only sort of air in which miners could work, in a deep colliery. Thus, at the St. Henriette colliery, although the temperature of the working-places was 103° Fahr., the air only contained 8·7 grains of water per cubic foot. This dry air absorbed the perspiration from the men's bodies, whereas if an effective spray-system had been in use, as suggested by Mr. Roscamp, the air would have been saturated with over 20 grains of water, and the men placed in such an enervating hot bath, that effective work would have been an impossibility.

He (Mr. Ashworth) did not consider that a "cloud" of dust

* "An Improved Apparatus for laying Dust in Coal-mines," *Trans. Inst. M. E.*, 1904, vol. xxviii., page 578.

† *First Report of the Royal Commission on Coal-supplies*, 1903, vol. ii., Minutes of Evidence and Appendix; Mr. W. N. Atkinson, questions 2,273 to 2,456, pages 94 to 103; Mr. Henry Bramall, questions 239 to 513, pages 11 to 22; Mr. John Gerrard, questions 741 to 873, pages 31 to 36; and Mr. Henry Hall, questions 922 to 1,028, pages 39 to 43.

was nearly so dangerous to the safety of a mine, as the small percentage of fine dust, which was constantly produced by the transit of the loaded tubs; and this was always floating in the air, whether there were any sprays or none. His (Mr. Ashworth's) experiments on safety-lamps* and Mr. H. Hall's experiments referred to in his (Mr. Ashworth's) paper† proved that a very small percentage of coal-dust was required to render a mixture of coal-dust and air explosive. This fact might be recognized by ascertaining the weight of coal-dust, if converted into gas and mixed with air, that would render a certain volume of air explosive. Prof. J. T. Beard, of Scranton, Pa., U.S.A., stated that one pound thus treated would, when mixed with 2,440 cubic feet of air, be explosive.

Mr. Roscamp referred to the explosion at the Universal colliery, and he (Mr. Ashworth) asked him to explain why the A and B districts of Prof. W. Galloway's plan,‡ corresponding with the York East and East districts of Mr. Robson's plan,§ were traversed by flame where they were naturally wet? The return-air from the A and B districts was practically saturated with moisture, and at the points *t* and *q*, it could only have carried ½ grain more.

The suggestion was made by Mr. W. C. Blackett that westrumite should be tried as a dust-layer.‖ Mr. M. Walton Brown was testing other dust-laying liquids, whilst Messrs. J. P. Kirkup and C. H. Merivale¶ in the previous discussion, and Messrs. W. N. Atkinson, H. Bramall, J. Gerrard and H. Hall, in the evidence referred to,** had shown that it was impossible to work a deep mine if moisture were added to the air as proposed by Mr. Roscamp, and therefore some other means must be used to lay the dust. Dry air was a positive necessity in a dry mine.

* *Trans. N. E. Inst.*, 1880, vol. xxix., page 149.

† *Trans. Inst. M. E.*, 1905, vol. xxix., page 12 *et seq.*

‡ "Report," by Prof. W. Galloway, *Reports to His Majesty's Secretary of State for the Home Department on the Circumstances attending an Explosion which occurred at the Universal Colliery, Glamorganshire, on May 9th, 1901*, by Prof. W. Galloway, Mr. S. T. Evans and Mr. J. T. Robson, 1902, Plate II., page 18.

§ "Report," by Mr. J. T. Robson, *Reports to His Majesty's Secretary of State for the Home Department on the Circumstances attending an Explosion which occurred at the Universal Colliery, Glamorganshire, on May 9th, 1901*, by Prof. W. Galloway, Mr. S. T. Evans and Mr. J. T. Robson, 1902, Plate I., page 36.

‖ *Trans. Inst. M. E.*, 1905, vol. xxix., page 22.

¶ *Ibid.*, vol. xxix., page 24. ** *Ibid.*, vol. xxx., page 127.

Mr. Henry W. Martin (Cardiff) wrote that Mr. Ashworth in his valuable paper made quotations, from the reports of H.M. inspectors of mines, that seemed to imply that they considered efficient watering to be the one necessary and sufficient preventive of explosions, or when an explosion had been initiated, to be a powerfully restrictive agent. In his (Mr. Martin's) opinion, however, in order to make watering effective against dust-explosions, the dust should be thoroughly wetted, and to do this with a moderate quantity of water, it was essential that the dust (as it accumulated) should by constant cleaning be maintained at a minimum. He (Mr. Martin) did not think that moisture in the air, in the form of vapour, would have any effect in preventing an explosion or in restricting the effects of an explosion; but, by frequent and liberal spraying, the air could be charged with small particles of water in a liquid form; and they would be carried by the air-current and deposited upon the surfaces of the mine, and thus efficiently damp the dust and prevent a dust-explosion, or, at any rate, mitigate the effect of an explosion once it was initiated. At ordinary temperatures, watering of the dust did not seriously interfere with the comfort or health of the workmen. Where underground temperatures exceeded, say, 90° to 96° Fahr., as suggested by Mr. J. P. Kirkup,* the question of copious watering was a different matter, and so far as his personal opinion went, he could not do better than quote from a portion of his evidence† given before the Royal Commission on Coal-supplies, dealing with the temperature and dampness of the air in which miners work:—

An increase of the temperature of the air, due to deeper and warmer mines, will increase its activity in absorbing moisture. There is, to my mind, but one effective and practical method of meeting these evils at very great depths; and that is, to augment the supply of pure dry air as the depth of the mine increases. It is as necessary that the supply of air should be dry as that it should be of ample quantity, and the matter of purity is as important as either. To obtain such a supply, the first matter to be considered will be increased ventilating power. Ventilating fans will be required of larger dimensions than those now in use for a colliery of a given capacity.

Airways will have to be enlarged, or an increased number must be adopted. To ensure dryness and purity, the ventilating current will have to be protected from all falling water and wet sides, roofs and floors. All intake-airways will

* *Trans. Inst. M. E.*, 1905, vol. xxix., page 24.

† *First Report of the Royal Commission on Coal-supplies*, 1903, vol. ii., Minutes of Evidence and Appendix, question 2,001, page 86.

have to be kept perfectly clean, and free from dust or any matter that would contaminate or make the air impure. The system of watering, so frequently adopted and strongly advocated, will have to be used very cautiously, or abandoned altogether, and some other means adopted for dealing with the dust question. Another matter which will have to be attended to, is the velocity of the air-current at the working-faces. This will have to be maintained as high as possible, consistent with safety. Men cannot work efficiently in a sluggish current at a high temperature.

I believe that, as mines get deeper, it will be found necessary to convey the air inwards in ways exclusively used for that purpose, and no hauling or other work done on them, only the necessary work of maintenance, so as to arrest the use of any water, and prevent the air from becoming impure. With such a pure supply of air, men will be able to work at a temperature higher, and with greater humidity, than can be done when the ventilation is not so good as I have indicated.

Mr. John Morris' paper on "The Unwatering of the Achddu Colliery, with a Description of the Riedler Express Pump," was read as follows:—

THE UNWATERING OF THE ACHDDU COLLIERY, WITH A DESCRIPTION OF THE RIEDLER EXPRESS PUMP.

By JOHN MORRIS.

I. The Unwatering of the Achddu Colliery.

Introduction.—The difficulties encountered in the unwatering of the Achddu colliery, being somewhat out of the ordinary, and having also in view the fact that one of the pumps used (the Riedler Express pump) is a comparatively new departure in pumping machinery, the author thought that a description of the operation, and of the performance of this pump in actual work, would be interesting to the members.

The Achddu colliery (owned by the Achddu Colliery Company, Limited) is situate at Burry Port, Caermarthenshire. A slant or day-drift is driven from the surface in the Gwscwm coal-seam, about 3¼ feet thick and dipping about 1 in 3: the slant being driven down practically to the full dip. The slant forms the intake-airway of the colliery, while a small shaft* sunk about 120 feet to this seam forms the upcast.

This mine had for several years been worked under the name of the Pemberton colliery, and the slant had been driven a distance of about 1,335 feet from the surface. An influx of water broke in at the bottom of the workings, and drowned out the colliery. On taking over the colliery, the Achddu Colliery Company, Limited, decided to unwater it by means of a portable electrically-driven Riedler Express pump.

An electrical power-plant was erected, comprizing a Crompton, 150 kilowatts, compound-wound continuous-current dynamo (its output being 300 ampères at 500 volts) driven through eight cotton-ropes, 1½ inches in diameter, by a tandem compound non-condensing engine with a high-pressure cylinder 16 inches

* This old shaft has been in existence for many years. Old miners, 120 years ago, referred to it as the pit of the "old men." Wooden pump-trees have been recovered from it in a fair state of preservation.

in diameter, and a low-pressure cylinder 26 inches in diameter by 32 inches stroke. The power was taken through two copper-wire cables (39 wires of No. 16 wire-gauge), bitumen-insulated, and having a double armouring of steel-wire.

All the electric motors were provided with rheostatic starters, having overload and no-voltage releases, and with shunt-regulators.

Express Pump.—The upper 300 feet of the slant was unwatered by means of a steam-pump slung in the upcast shaft. And thence downward the colliery was to be unwatered, by following down the old slant, and pumping the water to the surface by means of the Express pump (Figs. 1, 2 and 3, Plate IV.). This pump was designed to deal with a quantity of 375 gallons of water per minute against a head of 500 feet. It was driven through single-reduction gearing by a Crompton open-type compound-wound motor of 75 brake-horsepower at 450 volts. The pump, motor and starter were mounted together on a steel-girder carriage having wheels of 2½ feet gauge: the same gauge as the colliery tram-road. The tram-rails weighed 12 pounds per foot. The pump worked on a road laid on one side of the slant, while the tram-road was laid on the other side, so that the trams could pass the pump on their way to and from the face. This arrangement necessitated the widening-out of the old slant to a width of 14 feet: the original width being 6 feet. The arrangement of mounting the motor-starter on the pump-carriage, soon proved unsatisfactory, as, owing to the vibration of the pump, the starter continuously cut out the current. The starter was then taken to the power-house (the shunt-lead then extended from the motor to the starter in the power-house) and the engineman in the power-house had to stop and start the pump, as signalled by the pumpman. An ordinary switch was put on the pump-carriage, so that, in case of an emergency, the pump could be stopped by the pumpman.

This pump was introduced in May, 1903. When the author took charge of the colliery in November of the same year, the slant had been reopened for a distance of 450 feet, that is, 750 feet from the surface, with this pump. The average rate of opening-out was about 22½ feet per week, but six weeks previous to this, the pump had failed to cope with the water (the

make being about 175 gallons per minute) and it was being gradually drowned out. It was only a question of a stoppage of about two hours before the water would be up to the pump. The pump and carriage was off the road, and it was a question of more than two hours' stoppage before it could be got right; so that nothing could be done (as the valves of the pump could not be got at in the position where it was) but let it work as long as it could, as another pump was expected to replace it.

Scott-Mountain Pump.—This pump arrived a few days after the author took charge of the colliery. It was a three-throw pump, having rams 7½ inches in diameter by 12 inches stroke, running at 40 crank-revolutions per minute, driven through double-reduction machine-cut gearing by a shunt-wound open-type motor of 65 brake-horsepower at 500 volts: its capacity at this speed being 200 gallons per minute. The motor was fitted with a raw-hide pinion. The carriage for this pump, built at the colliery, consisted of four pitchpine balks, suitably braced and bolted together, and fitted with wheels for a road of 2½ feet gauge, the axles being 3 inches in diameter, with four pedestals fitted to each axle.

This pump weighed, when ready to work, mounted on its carriage, about 16 tons; and it was 17 feet 6 inches long, 6 feet 6 inches high and 6 feet 8 inches wide. It was got ready to work in about 14 days, and worked splendidly. (The Express pump had been drowned out a week previously, the motor only being removed, and the water had risen about 180 feet in the slant.) In working it rested against two stout props, which were put up in front of it, and it was also fastened to another prop put up behind it. After being lowered (before being started to work) it was always chocked up by wooden wedges, so as to relieve the wheels of part of the weight.

The suction- and delivery-pipes were 6½ inches in diameter, the suction-pipe having (next to the pump) a length of 20 feet of indiarubber hose-pipe attached, and it proved a great convenience in the handling of the suction-pipes. Attached to the hose-pipe, were ordinary wrought-iron pipes, 6½ inches in diameter with a snore-piece attached at their lower end. The suction-pipes were always, if possible, pushed down through the old slant in advance of the point that was being opened out.

The old slant was in many places almost closed; and, when this was the case, the men had to work in a depth of, perhaps, 2 feet of water, in order to clear out a place for the snore-piece, just as in the case of a sinking pit; but every effort was made to push the suction-pipes downward in advance of the face of the widened slant. When the snore-piece of the suction-pipes was a few feet below this point, the pump got its water quite clear, and it could keep the water down, as far as the suction-pipes extended. The operation of opening out the old slant would then proceed until within a few feet of the snore-piece, then another pipe would be added to the suction-pipe, which would then be pushed downward through the old slant for a distance equal to the length of the inserted pipe, which varied from 3 to 15 feet. In this manner, the opening-out was continued regularly until a point was reached from 65 to 70 feet below the pump: this represented a vertical suction-lift of about 25 feet. The pump was then lowered for a distance of from 30 to 45 feet, and the opening-out of the slant then proceeded as before. The pump was never nearer than 25 feet, nor farther than 70 feet from the face.

In addition to the men engaged in the actual work of opening out, another set of men were engaged in laying the pump-road, which had to be substantially laid; they erected at a measured distance, the two props against which the pump would rest after lowering it; and, generally, they prepared everything ready for lowering the pump (which was done by the winding-engine) so as to delay as little as possible the work of opening out the slant.

The electric cables were carried along the side of the slant, on horizontal pieces of wood fixed for the purpose. A length of about 450 feet of both cables was coiled on the side of the slant. When lowering the pump, sufficient cable would be uncoiled, and easily dragged down the distance that the pump would be lowered.

The time taken to disconnect the cables, suction-pipes and delivery-pipes, lower the pump, connect together again and start, was generally about 3 hours. There was not much time to lose, as the water rose in the slant about 10 feet an hour when the pump was stopped. The suction-pipes and delivery-pipes were both provided with expansion-pipes, which proved of great convenience.

The only difficulty found in working this pump, was, that the suction-valves sometimes stuck: this being due to the fact that the pump was designed to work horizontally, while it had to do its work on an incline of 1 in 3.

With this pump, the slant was opened out for a distance of 360 feet, at the rate of about 36 feet per week. The road was 14 feet wide and 7 feet high, and supported every 3 feet by sets of timber, about 10 inches in diameter.

At this point, about 1,110 feet from the surface, it was decided to discontinue driving the slant downward, until some very extensive flooded workings (which were being bored to, in a road driven towards them) were tapped. These workings (which formed part of another old colliery) had been closed for about 50 years. The Burnside boring apparatus* was used, and by its use, the old workings were successfully tapped at a pressure of 152 pounds per square inch: the bore-hole being 48 feet long. The Riedler Express pump was put down in a lodge-room, to deal with this water, and preparations were again made to continue the driving of the slant.

For this purpose, a small three-throw pump was put down. It was designed to work on an incline of 1 in 3, and had a capacity of 200 gallons per minute, when running at 50 crank-revolutions per minute. It had trunk-plungers, 7 inches in diameter by 10 inches stroke, and was driven through double-reduction gearing by a Bruce-Peebles shunt-wound motor of 15 brake-horsepower at 500 volts. This pump being only 4 feet wide and 4½ feet high, the road was reduced to 10 feet wide and 6 feet high. With this pump, the remaining 225 feet of the old slant was reopened in 24 days. At the bottom of the old workings, a sump was driven; and all the water being caught at this point, the slant was driven further downward, in the coal, quite dry.

The operation of reopening was the same with this pump, as with the Scott-Mountain and Express pumps. It delivered its water to a sump, from which either the Express pump, or the Scott-Mountain pump, pumped it to the surface; both of these pumps were connected to the sump, to which would flow also the water from the bore-hole already referred to.

* *Trans. Inst. M. E.*, 1902, vol. xxiii., page 74.

These two pumps did not work together at the same time; while one would be working, the other would be standing idle, and the flow of water from the bore-hole would have to be regulated according to which of the two pumps was in use. The total amount of water made, apart from that from the bore-hole, was about 175 gallons per minute. The reasons for keeping one of the pumps idle, were, that the cable was of insufficient capacity, and there was only one line of delivery-pipes, 6½ inches in diameter. Further, the motors of the two pumps were not built for the same voltage; the Express pump gave its ordinary speed of 200 crank-revolutions per minute, at 450 volts, while the Scott-Mountain pump developed its ordinary speed of 40 crank-revolutions per minute at 500 volts.

While using these portable pumps, it was found advantageous to dispense with the foot-valve usually put in the suction-inlet, as, sometimes, the snore-piece became blocked by dirt, chips, etc., gathering round it; when this happened, all that was necessary to be done, was to stop the pump, open a valve fitted on a pipe that formed a bye-pass from the delivery to the suction, and the pressure of water that flowed through, cleared the débris from the snore-piece in a few seconds. This bye-pass arrangement was also very convenient when starting the pumps, as, on opening the bye-pass valve, the pressure on the pump was relieved and the pump started against a light load, and the relief-flow of water was conducted back to the suction-pipe.

II. The Riedler Express Pump.

Riedler Express Pump.—The Riedler Express pump (Figs. 1, 2, 3 and 4, Plate IV.) was designed for a capacity of 375 gallons of water per minute against a head of 500 feet. It is a two-throw pump, having rams, 6⅝ inches in diameter by 9 inches stroke, running at 200 crank-revolutions per minute, and driven through single reduction machine-cut cast-iron gearing by a Crompton open-type compound-wound motor of 75 brake-horsepower running at 500 revolutions per minute. The motor-pinion, U, gears into a wheel, V, on the crank-shaft, A, actuating the rams, B, which pass through the suction-chamber, C, into the barrels, D. E and F are air-vessels fitted with gauge-glasses, in order to show the height of water in each. E is the

suction air-vessel fitted on the suction-chamber, C. F is the delivery air-vessel, fitted on the delivery-pipe, G, on which, also, is placed a retaining-valve, H, fitted with a bye-pass valve; the retaining-valve is hinged on a spindle (working through a stuffing-box) by means of which it is laid full open when working, giving a clear passage to the water, the valve being closed only when necessary. I is the inlet, 8 inches in diameter, to the suction-chamber, C.

A small compound air-charger, R, having a low-pressure plunger, 3 inches in diameter by 2·7 inches stroke, and a high-pressure plunger $1\frac{1}{2}$ inches in diameter by 1·8 inches stroke, is bolted to the side of the pump. The air-charger is actuated by a rod, J, worked by a small crank-pin, screwed into the end of the crank-shaft. The air-charger exhausts the air through a small sponge-filter from the suction air-vessel, and delivers it into the delivery air-vessel: the air-charger runs at the same speed as the pump. Should the supply of air in the suction air-vessel be insufficient, air can be let in by means of a small cock: also, should the supply of air from the charger be too great, air can be let out of the delivery air-vessel; it is found best to keep about 1 inch of water showing in the gauge-glasses.

A displacement-lubricator, K, for the forced lubrication of the rams, was bolted to the pump-bed; it was attached to a small pipe from the delivery-pipe of the pump, the water from which displaced the oil from the lubricator and forced it through a pipe, L, on the rams.

The carriage of the pump was provided with four pairs of clamping jaws; by means of which it was fastened to the rails on which it stood when working on the slant, in order to steady it in working.

The body of the pump consists of two main castings: the suction-chamber, C, and the two outer barrels, D, which are made in one casting.

Fig. 4, a section on the line YZ of Fig. 3 (Plate IV.), shows the construction of the barrels, rams, valves, etc. Each outer barrel, D, contains an inner barrel, *a*; and the outer end, *b*, forms the seating of the delivery-valve, *c*. The inner end of the inner barrel contains a gunmetal guide-ring, *d*, in which works the annular suction-valve, *e*. Each ram passes through a stuffing-box, *f*, which passes through the suction-chamber, C.

The inner end of the stuffing-box forms the seating, *g*, of the suction-valve. The stuffing-box, *f*, is a separate casting for each ram, and is held in place by the cast-iron ring, *h*. The ram is attached to the cross-head by the steel-rod, *i*, which passes through it. The inner end of the steel-rod carries a gunmetal buffer, *j*, which, at each stroke, closes the suction-valve.

The suction-valve is constructed of birch-wood, fitted, with the grain end-on, into a channel-section annular brass-ring. The ram passes through the suction-valve. Into the guide-ring, *d*, in which works the suction-valve, *e*, is inserted an india-rubber ring, *l*, against which, in opening, the suction-valve may strike. The buffer, *j*, also carries an indiarubber-ring, *m*, which is the part of the buffer that strikes the suction-valve in order to close it. Interposed between the ram and the buffer are a number of stencil-brass liners, *n*, for the purpose of adjusting the buffer, in order to take up any wear in itself, or in the suction-valve. From the construction of the buffer, it will be seen that it is not rigidly fixed to the steel-rod that carries it, but is kept in position by a brass-bush, *o*, and the indiarubber-cylinder, *p*, the brass-bush being secured to the rod by the box-nut, *q*, so that any shock that would occur by the buffer striking against the suction-valve, would be taken up by the indiarubber-cylinder.

The delivery-valve consists of two annular brass-rings, c_1 and c_2, let into a gunmetal frame, *c*, the whole being kept against the seat by means of the bolt, *r*, which is screwed into the end of the inner barrel, and transmits its pressure, on to the valve, through the indiarubber-cylinder, *s*, against the resistance of which the delivery-valve opens. The delivery-valve is provided with leather sealing-rings, *t*, which further secure its efficient action.

The action of the pump is as follows: The water enters the suction-chamber, C, and on the opening of the suction-valve, *e*, on the outstroke of the ram, enters the inner barrel. At the end of the outstroke, the buffer closes the suction-valve; and on the instroke, the water is forced out against the resistance of the indiarubber-cylinder of the delivery-valve; again, at the commencement of the outstroke, the indiarubber-cylinder being in compression, instantly closes the valve; and, at the same time, the suction-valve would open, and more water would enter into

the inner barrel. It will be noticed that the suction-valve is both opened and closed on the outstroke of the ram.

On being forced out of the inner barrel, the water fills the annular space between the inner and outer barrels, and thence enters the delivery-pipe; so that the outer barrel is always subjected to a bursting strain, while the inner barrel is subjected to a compressive strain, except on the instroke of the ram, when it is subjected to a very slight bursting strain: the whole bursting strain being only that required to open the delivery-valve.

Each outer barrel is fitted with a starting-valve, M, 2 inches in diameter, so that in starting the pump, the pressure can be relieved and the pump started light. These valves are gradually closed as the pump attains its working speed. There is a small passage, *u*, fitted with a small cock, through which, before starting, any air that may be in the inner barrel can be let out.

P is a small spindle stop-valve, screwed through the cover of the outer barrel, while its inner end, which forms the valve, closes a small port, *v*. On unscrewing this valve, water can re-enter the inner barrel; so that, if from any cause the water cannot enter the suction-chamber fast enough, then on unscrewing this valve, sufficient water can re-enter the inner barrel, so as to enable the pump to run without shock.

For the lubrication of the rams, the oil-pipe from the lubricator enters a small ring, *w*, in the stuffing-box; and the oil flows to the rams, through small holes in this ring. The writer did not see the lubricator in use, it was stated to him that it was very uncertain in its action, and it was consequently thrown out of use.

The Causes of the Failure of the Pump.—When the writer took charge of the colliery he found the condition of affairs as previously stated: the pump and carriage was off the road, the commutator was sparking and was grooved nearly $\frac{1}{8}$ inch deep, new carbon-brushes were worn down in a few hours, the cranks were kept cool only by having a stream of water constantly flowing on them, and the pump was gradually being drowned by a quantity of water not equal to 50 per cent. of its designed capacity.

After the pump was recovered, it was found, on examination, that the leather sealing-rings of the delivery-valves were in

fragments; some of the pieces were wedged tightly beneath the valves, thus allowing part of the water to re-enter at each stroke; and the seatings were in fair condition. About ¼ inch of the wood in the suction-valves was worn down, so that the buffers could not close the valves properly. The seatings of the suction-valves were eaten away into grooves and holes: some being ¼ inch deep. The immediate cause of the failure of the pump, was due, no doubt, mainly, to the bad state of the suction-valves and their seatings: and it was doubtless an error of judgment to provide a pump with cast-iron valve-seatings to pump out old-mine water. The armature of the motor was soaked with oil, and one of its coils was grounded to the core; and this was undoubtedly the chief cause of the sparking at the commutator, although the grooving of the commutator was probably in great part due to the vibration of the pump. The air-pump was also out of order, and the pump ran with considerable shock.

After being brought out of the mine, the pump and the motor were thoroughly overhauled. The seatings of the suction-valves were bored out, and gunmetal seatings inserted and secured by countersunk brass-screws, *g* (Fig. 4, Plate IV.).

The pump was then placed in a pump-room, the pump being arranged in relation to the sump, so that the water flowed into the pump; the circumstances now being such as to give it every possible advantage in working. Under these conditions, the pump did its work efficiently, and the water flowed out of the delivery-pipe in a perfectly steady stream. Several test-runs of 6 hours' duration were made, but in ordinary working, the pump was stopped every 2 hours for oiling and examination. The pump ran for about four months, and as far as the quantity of water delivered, and the freedom from shock was concerned, it gave satisfaction.

The chief disadvantages in working the Express pump were: It created great noise; it used a large amount of oil; it required constant examination, as there was a tendency for various parts to work loose; and, owing to the vibration of the pump, the brushes had a tendency to jump on the commutator, causing grooving and sparking.

After four months' running, one of the connecting-rods broke. On overhauling the motor, it was found that the excessive dampness of the mine had considerably affected it. Every part of

the motor was well dried before restarting it. About six weeks later, the series-coils of one of the field-magnets fused, and a ground occurred in the armature: these were put right at the colliery, and the pump was running when the author gave up charge of the colliery at the end of last year.

When used as a stationary pump, many of the defects in this class of pump could easily be remedied. By making it a rope-driven pump, the motor would be free from vibration, and the great noise would be removed. A system of forced lubrication with recovery and re-use of oil could also easily be adopted.

The small size of the Express pump, in comparison with its capacity, gives it a decided advantage in mining work; but, on the other hand, the great vibration militates considerably against its use as a portable pump.

Experiments.—The following are particulars of a test taken by the author, of the efficiency of the Express pump. The sump from which it drew its water was slightly higher than the pump, so that the water flowed into the pump at a pressure of about 1 pound per square inch. The sump was 61 feet long, 12½ feet wide and 5½ feet deep. No water was made in the sump, and all the water that flowed into it could be diverted. For the purposes of the test, the sump was allowed to become three-quarters full, and then all further water was prevented from entering it. A stick was fixed vertically in the sump, and the time that the pump took to lower the water 2 feet vertically was noted, the stick having on it two notches 2 feet apart. This time was found to be 25 minutes.

The body of water removed was (61 feet × 12½ feet × 2 feet =) 1,525 cubic feet, or 61 cubic feet or 380·79 gallons or 3,807·9 pounds of water per minute.

During this time, readings were taken at intervals of 2 minutes of the volt and ampère-metres, at both the generator and the motor; and the speed of the pump was taken. The average of twelve readings at the generator was 470 volts and 101 ampères; and of twelve readings at the motor, 451 volts and 101 ampères. This showed a pressure-drop of 19 volts or about 4 per cent.

The pump had a speed of 200 crank-revolutions per minute.

Mines.—There are two companies working on this dyke: the Ontario Corundum Company, in Carlow township, Hastings county, and the Canada Corundum Company, in Raglan township, Renfrew county, the last-mentioned company having taken over the wellknown Craig-mine and other deposits, covering an

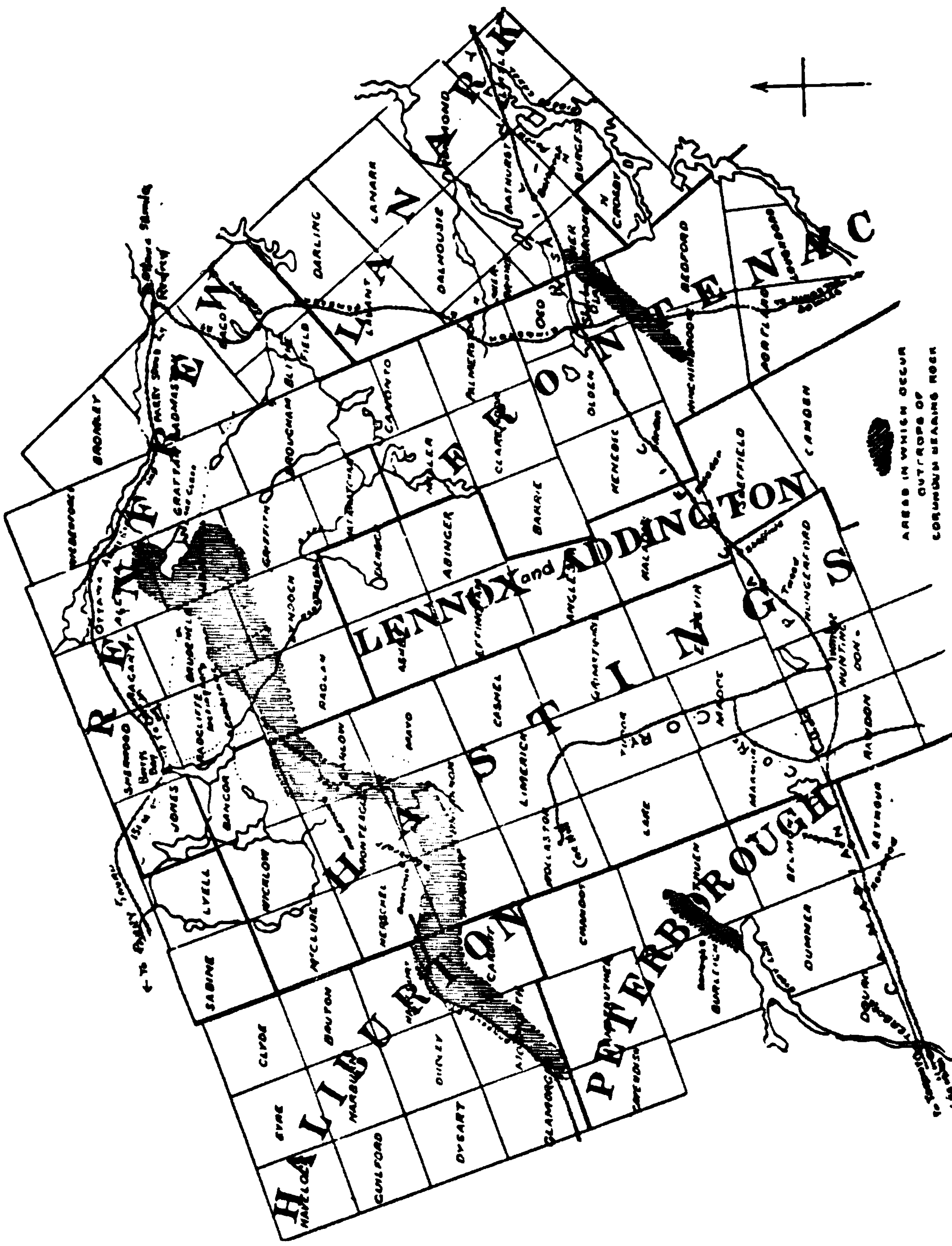

Fig. 1. -Index-Map of Corundum District. Scale, 26 Miles to 1 Inch.

area of 2,000 acres in the counties of Renfrew and Hastings. At present, the works are confined to Craigmont, where the crushing and concentrating plant is situated, and corundum-ore is quarried from the southern face of the hill, 500 feet high. In

some places, considerable stripping is done, of sand and gravel to the depth of 5 feet; at some points, the corundum-bearing rock crops out, showing the corundum-crystals imbedded in the rock and polished down level with the rock by glacier-action. At other points, where the corundum-bearing rock has been exposed to the weather, the corundum-crystals stand out boldly. The mineral is quarried in a series of benches up the hill, the faces running from 1 foot to 15 feet thick, and it varies in richness from 8 to 17 per cent. There are rich zones in the dyke going down diagonally south-east; in these zones, rich pockets of big nodules of almost pure corundum are found associated with crystals of white mica. Cutting through this deposit, a number of dykes are observed carrying hornblende in the same form as the corundum-crystals and readily mistaken for corundum. This dyke varies in thickness from 2 to 10 feet, when the corundum comes in again higher up the hill. In a series of little pockets of corundum-bearing ore, the width will run from 40 to 100 feet, and the ore is found in layers or in benches. The surface-rock will be ore; beneath this is a thickness of barren gneiss-rock, varying from 1 foot to 6 feet; beneath this occurs another layer of corundum-bearing ore, 3 to 4 feet thick; another layer of waste and corundum-ore follows in succession, until a depth of 25 to 30 feet is attained. A granitic rock occurs below, but it has only been penetrated in three or four places: at one place, within a distance of 32 feet, no sign of corundum-ore was found.

On the property of the Ontario Corundum Company, 6 miles to the west of Craigmont, the occurrence and composition of the dyke are practically the same, with narrow bands of black micaceous schist and coarse pink pegmatite in the syenite. A rock-bluff is worked with a perpendicular face going in east on the dyke, with an average of 10 per cent. of corundum-crystals in the face.

The following analyses of corundum-crystals show the purity of the mineral:—

Sample.	Alumina Al_2O_3.	Ferric Oxide Fe_2O_3.	Insoluble Matter.	Loss on Ignition.
I.	92·62	—	1·13	2·04
II.	93·29	0·36	—	1·91
III.	94·72	0·32	—	1·14

The assay-tests are made for crystalline alumina and magnetic

iron and for loss on ignition. In clean corundum-crystal, a small percentage of iron, from 0·5 to 2 per cent., is found combined with the corundum.

On the property of the Canada Corundum Company, the mining is done in the usual way by means of air-drills and dynamite. The holes are drilled (Fig. 2) 14 and 15 feet deep, and a series of as many as twenty holes are sometimes fired off by

FIG. 2.—ROCK-DRILLING.

means of the electric battery. A large quantity in big pieces is thrown down, and they are block-holed (Fig. 3) and bull-dosed with dynamite down to suitable sizes for handling by the cullers, as it is very necessary to cull or select the ore. The percentage of corundum does not run high enough to allow of milling all the ore coming from the mine, without sorting out the low grade, as the lowest grade of ore fed to the mill requires to be higher than

the amount which is lost in the tailings; it is also necessary to prevent as much as possible large pieces of magnetite, iron-pyrites, or hornblende, from going to the mill, as they are difficult to remove when concentrating to 95 per cent.

In the very fine fissures, thin splashes of molybdenite (running high in molybdenum sulphide) are found, but this ore does not occur in any quantity, enough for samples only. It is stated that there is a vein of molybdenite in the neighbourhood.

FIG. 3.—BLOCK-HOLING, WITH A HAND-DRILL.

The drilling of the corundum-bearing rock, either by hand or by rock-drills, is not difficult; but the diorite or crystalline limestone offers greater resistance to fast drilling.

From the open quarries on the face of the hill, the ore is brought down in stone boats and trucks by teams to the tramway where it is loaded on to cars, carrying 3 to 4 tons. The

cars run on a tramway into the top of mill (Fig. 4); before entering the mill the car-load is weighed and an exact tally kept of the number of tons which go into the mill every day (in wet weather, an allowance is made for the moisture in the ore). The cars are drawn by horses, and can handle 150 tons in 10 hours.

Mill.—The mill (Figs. 5 and 6) is situated at the east end of the southern face of the hill on which the corundum-ore is quarried. The tramway, already mentioned, comes from the weighing-machine and enters at the top of the mill: the cars are of the flat-top type and tip on both sides into the bin below. The bin is square

FIG. 4.—TRAMWAY FROM THE QUARRIES TO THE TOP OF THE MILL.

and flat-bottomed, with a capacity of 400 tons. The shute for feeding the crusher is near the centre of the bottom of the bin, and comes out to the ore-crusher; and alongside of this shute, a man stands and feeds the crusher, of the Farrell type of Blake crusher, 15 inches by 24 inches, running at 250 revolutions per minute and crushing down to 2½ inches. The ore, after being crushed, drops on to a Robbins conveyor-belt, 18 inches wide and 85 feet long, travelling at a speed of 300 feet per minute, with 20 per cent. of an elevation to the delivery-end.

The stream of ore coming from the conveyor-belt is divided into three, and fed by short shutes into three smaller crushers, two of them being the Farrell type of Blake crushers, 6 inches by

20 inches, and one a Gates gyratory type A crusher. These three crushers reduce the ore to $\frac{3}{4}$ inch and less, and drop it into another large bin underneath of 400 tons capacity.

From the underside, at the face of the bin, the ore is fed into coarse rolls by means of a Challenge-feeder, the ore dropping from the disc of the feeder into the screen-shute and straight into the rolls: the screen taking out all fines allows the rolls to do better work. The Challenge-feeder stood below the centre of the ore-bin, and the ore was carried to the rolls by a belt-conveyor; but this was discarded, owing to the amount of ore spilled, and in order to permit of the attendant getting to the back part of the rolls so as to tighten the springs.

FIG. 5.—VIEW OF THE MILL FROM THE SOUTH, SHEWING THE QUARRIES AT THE LEFT-HAND SIDE.

The ore, after passing through the coarse rolls, drops down, and is divided between two trommels, 13 feet long and 3 feet in diameter, running at 20 revolutions per minute, sloping 1 inch to the foot, the screens having 4 millimetre holes. The undersize passes downward into the vertical elevator, and the oversize passes to two sets of rolls and then into the same elevator. The elevator is an indiarubber-belt with buckets bolted on (the buckets being 18 inches long, 6 inches wide and 6 inches deep), running at 350 feet per minute. All the crushed ore is raised by this elevator in the form of a watery pulp to the top of the

mill, where it is divided into two sets of five trommels in each set. Each trommel, 3 feet in diameter and 13 feet long, 20 revolutions per minute and slope 1 inch to the foot, is driven by a sheave-pulley and rope-drive on the over-size end.

The pulp enters the two coarse trommels, the first 6 feet being covered with screens perforated with 4 millimetres holes, 4 feet with 6 millimetres holes, and 1½ feet with 8 millimetres holes. All pulp passing through the 4 millimetres holes goes to the next trommel, that passing the 6 millimetres holes goes downward to two sets of double three-compartment iron Hartz jigs; and that passing through the 8 millimetres holes passes downward

FIG. 6.—VIEW OF THE MILL FROM THE EAST.

through wooden spouting lined with steel-plate to a set of double two-compartment wooden Hartz jigs. The over-size, from these two trommels, goes downward to the roll-floor and, being recrushed, comes back through the same elevators. The pulp passing through the 4 millimetres holes on the first set of trommels passes to the second trommels, covered for the first 6 feet with screens having 2 millimetres holes, the pulp passing through the 2 millimetres holes goes on to the next set of trommels, and that passing over the 2 millimetres holes is sized on the next 5 feet of the trommel with 2½ millimetres holes; the pulp passing through the 2½ millimetres holes is treated on

six Overstrom tables: this size is a little large for these tables, but it is done in the meantime for lack of jigs. The over-size of the $2\frac{1}{2}$ millimetres holes goes downward to a double three-compartment iron Hartz jig. The pulp passing through the 2 millimetres holes on the second set of trommels then passes to a third set, of which the whole length is covered with screens having $1\frac{1}{2}$ millimetres holes; the undersize goes to the next set of trommels and the over-size to three Overstrom tables. The fourth set of trommel-screens has 1 millimetre holes, the under-size going to the fifth set and the over-size to the concentrating-tables. The pulp passing through the fifth trommel and the $\frac{3}{4}$ millimetre holes goes into a V box, and (the heavy particles settling) is fed to a concentrating-table and the surplus water is run into the tail-race. The twenty Overstrom and four Wilfley concentrating-tables, the two sets of double three-compartment iron Hartz jigs, and the double two-compartment wooden Hartz jigs, are placed on the floor below the trommels. The screen-area of the iron jig is 24 inches by 36 inches, and the screens are of the same sizes in the hole as the trommel which supplies the material, but the top of the screen has $1\frac{1}{2}$ inches of over-size material for a head. The speed of the jigs is 220 revolutions per minute; for the fines, up to 170 revolutions per minute; for the coarser sizes, the stroke is $\frac{3}{4}$ to 1 inch.

The product of the jigs' first hutch goes to the finishing-rolls on the roll-floor below, where it is crushed and goes to bin, being finished in the crushing part of the mill; the second and third hutches of the jigs, not being so clean, go to the rolls again and are crushed finer, and, owing to the want of a separate elevator and screen, they have to go back into the main elevator where, if fine enough, they will go to concentrating-tables, and if coarse, will be returned to the jigs. Tests made on the product of the jigs showed that the first hutch cleaned it to about 50 per cent. of corundum, and the second and third hutches to 35 or 45 per cent. of corundum: that is, from an ore which carries 10 per cent. of corundum and 6 to 7 per cent. of magnetic iron. The tailings from the jigs showed a loss of 3 per cent., but, as they were much overloaded, this did not give a fair showing; and, no doubt, with ample jig-capacity, the losses would be reduced by 50 per cent.

The following is about the average percentage of corundum in the end-products:—

	Per Cent.
Ore fed to mill	10½
Jig-concentrates	50
Jig partial-concentrates	40
6 millimetres screen, jig-tailings	3
4 millimetres screen, jig-tailings	3
2½ millimetres screen, jig-tailings	3
Table-concentrates	60
2½ to 2 millimetres, table-tailings	2
2 to 1½ millimetres, table-tailings	2
1½ to 1 millimetres, table-tailings	2
1 millimetre to zero, table-tailings	2
Magnet-tailings, coarse	7
Magnet-tailings, fine	3
Average	5
Rewash-table tailings	5
Total mill-tailings	5

The corundum is cleaned to 90 or 95 per cent.

On the same floor as the jigs, are the Overstrom and Wilfley concentrating-tables; and on an intermediate floor are six more Overstrom tables, to treat the middlings from the preceding Overstrom tables.

The losses from the concentrating-tables vary from 1½ to 2 per cent., principally carried off floating in the water; as, in the crushing of the corundum-crystals, owing to the hardness and the strain which is required to crush it, a percentage of the corundum goes to very fine powder and floats off in the water. The product from the concentrating-tables and the finishing-rolls is spouted into a small elevator, which raises it to another trommel for sizing, before being run into storage-tanks. No. 12 mesh is the size of screen on this trommel, and all coarser than this to No. 10 mesh is rejected, and goes back to the finishing-rolls and is crushed smaller. The corundum-concentrates are now deposited in the five storage-tanks; they are also used as filter-tanks to take off the moisture, and are fitted with a little false bottom for drainage. The corundum-concentrates, which now run about 50 per cent. of corundum, are then sent from the crushing department to the grading room.

In the crushing part of the mill, there are four sets of heavy rolls, 14 inches by 40 inches, with shafts, 10 inches in diameter, fitted with brass slieves, which slip on to the shafts and take all wear. The roll-shells are made of Hadfield manganese-steel, and do the work with very little wear, and the jaw-plates on all the crushers are made of the same material.

The Gates rolls, 14 inches by 24 inches, crush the product from the second and third hutches of the jigs. Adjacent are the Colorado or finishing rolls, 6 inches by 30 inches. There is another set of smaller rolls, but they have not been set to work yet.

The intention, when this part of the mill was built in 1903 and finished in the beginning of 1904, was to crush everything in the rolls small enough to concentrate on the Overstrom and Wilfley tables. This was found to be impossible, owing to the high percentage of fines, and the large amount carried off in the tailings in the form of fine slimes; the demand for the very fine sizes is small, and they are not so easily cleaned as the coarser sizes.

The crushing part of the mill containing the aforesaid machinery is a building 145 feet long, 36 feet wide, and 85 feet high, with five floors. On the second main floor is the machine-shop, equipped with a lathe, drilling-machine, and two small shearing-machines worked by hand.

The engine-house is equipped with a Corliss engine of 225 horsepower, a Corliss engine of 125 horsepower, and an auxiliary engine of 20 horsepower.

The first engine transmits power by means of six cotton-ropes, 1½ inches in circumference, to the main shaft on the same floor for driving all the jigs and concentrating-tables, trommels and the large elevator in the top of the building, also driving all the grading machinery in the grader-building by a rope-drive from the same shaft. The other six grooves on the engine-pulley drive the main shaft for the roll-floor by means of one continuous rope with a tightener-pulley and a balance-weight. This arrangement is being taken out, as in the event of this rope breaking, all the machines on this engine are stopped until the rope is straightened out and replaced. This means a lengthy

stoppage of several hours, whereas, if the ropes were all single drives, the breakage of a rope would cause no stoppage, as the other five would have sufficient power to drive the full load until the first stop, when another rope could be slipped on to it, having been prepared and spliced over the two shafts. From the main shaft of the jig and table floor, a rope-drive goes back into the engine-room to drive a small dynamo of 220 lights of 16 candlepower capacity. The little auxiliary engine runs this dynamo by means of a belt and countershaft, in the event of any stoppage of the large engine, and at the same time it runs the machine-shop for repairs.

The second engine, of 125 horsepower, runs the crushers and a small Root pump. The power is transmitted from the engine to the countershaft by a continuous manilla rope, 1½ inches in circumference, with a tightener-pulley: this also is being changed to single ropes.

In the same room as the engines, is a cross-compound air-compressor with intermediate and after-coolers, condenser, and air-receiver, having an air-capacity of 1,700 cubic feet of free air per minute and compressing it to 100 pounds per square inch, thus providing the quarries with sufficient air to run about thirty drills.

Steam is supplied to the engines from three return tubular boilers, 5 feet in diameter and 18 feet long, built up with bricks. Wood fuel is used, dry pine, maple, birch and poplar being the principal woods, the consumption amounting to 25 to 30 cords per 24 hours. The boilers are placed in a building apart from the mills.

The water to supply the crushing and concentrating part of the mill, is pumped by a Root pump from the basement of the grader-building, to a tank placed behind the first set of coarse rolls. This pump has a capacity of 1,000,000 gallons per 24 hours, and throws it against a head of 60 feet. From this tank, the water runs to the rolls, tables, jigs and launders. A jet of water is used to feed the ore into the rolls, and to keep down any dust.

Grader-building.—The grader-building is 135 feet long, 60 feet wide, and 80 feet high. The concentrates are brought into this building by a conveyor, and dropped on to a dryer.

The double-decked dryer, made of iron-pipes, $1\frac{1}{4}$ inches in diameter, is heated by exhaust and live steam. The wet concentrates are distributed from the conveyor upon a No. 4 mesh wire-screen, and as the stuff drys it drops through, on to a conveyor-belt, thence to an elevator, and is raised to the top of the building. The stream of concentrates is then divided over magnetic separators, one being of the cone and the other of the drum type. The concentrates contain 12 to 15 per cent. of magnetic iron: the non-magnetic concentrates go down to the splitter on the floor below and the magnetic iron, containing 4 to 5 per cent. of corundum, is dropped outside of the building for further treatment.

Roughing splitters, with three screens, divide the concentrates into three sizes: No. 1 takes all sizes, from 8 to 24 meshes inclusive, and sends them to No. 1 graders; No. 2 takes all sizes, from 30 to 70 meshes inclusive, and sends them to No. 2 graders; and No. 3 takes all sizes from 80 to 200 meshes inclusive, and sends them to No. 3 graders.

The roughing grader gives sizes passing through the screens; No. 1 is divided into sizes 24, 20, 16, 14, 12, 10 and 8 is over-size; No. 2 into sizes 70, 60, 54, 46, 36, 30 and 24 is over-size; and No. 3 into 200, 180, 150, 120, 100, 90, 80 and 70 is over-size. These products all go into bins above the rewashing tables and Hooper air-jigs. Steel-wire screen-cloth is used, from 8 meshes to 30 meshes; and silk screen-cloth is used for all of the other sizes, from 36 meshes to 200 meshes.

The Hooper air-jig is a good machine for concentrating dry-sized concentrates; it works well on concentrates from 24 meshes to 70 meshes, and gives four grades of produce from 50 per cent. corundum, as follow: Firsts or heaviest portion, magnetite and pyrites which have escaped the magnetic separators are extracted and sent to piles outside of the building. Seconds or lighter portion, is clean corundum 90 to 95 per cent. pure. Thirds or middlings, are held for retreatment, until a quantity is accumulated. And fourths, tailings or waste carrying off 4 to 6 per cent. of corundum. The clean corundum passes from the Hooper jigs to an elevator, which raises it to the top of the building.

Five Wilfley rewash-tables are used for cleaning up the coarse and the fine sizes. The Wilfley tables, running at 250

revolutions per minute, treat the fines, and the Wilfley table treating the coarse sizes runs at 215 revolutions per minute; the coarse tables have a stroke of $\frac{3}{4}$ inch and the finest table a stroke of $\frac{3}{8}$ inch. The products are: Firsts, on the high side of the table, a little magnetite and pyrites. Seconds are clean corundum, 88 to 90 per cent. Thirds or middlings are retreated on the same table. And fourths, tailings or waste containing 5 per cent. of corundum.

The clean corundum from the rewash-tables is carried to the second deck of the dryer, dried and dropped down to the conveyor, taken to the clean elevator, and goes to the top of the building along with the corundum from the Hooper jigs; then it goes over the finishing magnetic separator, drops through the floor, and passes the final magnetic separator. The process leaves a corundum carrying from 1 to $2\frac{1}{2}$ per cent. of iron, in the form of combined iron in the crystal corundum.

The corundum leaving the magnetic separator goes to the finishing splitters, of the same type as those already mentioned. This last operation must be carefully effected, as the exact sizing is very important to wheel-makers and users of loose corundum.

From the finishing-grader, the product drops into bins in the floor, from which it is drawn into bags containing 100 pounds. Samples are taken from all the sizes each day, before the bags are sewn up, and as soon as the results are sent from the assay-office, the grade of quality is marked on each bag, and it is then ready to be sent to market.

Three grades are made to suit the wheel-maker. The vitrified wheel requires the highest grade, the silicate-wheel takes the next grade, and the third grade goes to the cement-wheel maker and the polishing trade. The corundum for vitrified wheels varies from 90 to 95 per cent. pure. The silicate or chemical wheel is made with silicate of soda as the binding material. The binding-materials used in the cement-wheel are shellac, indiarubber, linseed-oil, etc.

The cost of producing finished corundum, including mining, milling, concentrating, sizing, packing, office-expenses, insurance and general charges, has not yet been reduced below £8 (40 dollars) a ton; but with a well-equipped mill, crushing 150 tons

per 24 hours of a grade of ore containing 10 to 12 per cent. of corundum, the cost should not exceed £6 to £7 (30 to 35 dollars) per ton.

The PRESIDENT (Mr. T. W. Benson), in moving a vote of thanks to Mr. Kerr for his interesting paper, said that the Institute was frequently indebted to colonial members for contributions to the *Transactions*.

Prof. H. LOUIS seconded the resolution, which was cordially approved.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

EXCURSION MEETING,
NOVEMBER 15TH, 1905.

DAWDON COLLIERY.*

The boring of the holes for the freezing-tubes, to a depth of 484 feet, was commenced in May, 1903.

The freezing-plant was connected to the Castlereagh shaft on April 22nd, 1904, and to the Theresa shaft on June 10th, 1904.

Castlereagh Shaft.—Sinking in the frozen ground was commenced on November 1st, 1904, at a depth of 203 feet 2 inches (Table I., and Plate V.).

TABLE I.—SECTION OF STRATA SUNK THROUGH IN THE CASTLEREAGH SHAFT, DAWDON COLLIERY.

No.	Description of Strata.	Thickness of Strata. Ft.	Ins.	Depth from Surface. Ft.	Ins.
1	Soil	1	0	1	0
2	Clay	5	6	6	6
3	Gravel	4	6	11	0
4	Strong marl, with limestone-girdles ...	50	10	61	10
5	Limestone, with strong marl-partings	32	7	94	5
6	Marl, with gullets ...	84	7	179	0
7	Hard grey limestone	34	6	213	6
8	Yellow limestone, mixed with red marl	13	2	226	8
9	Hard grey limestone	65	7	292	3
10	Grey and yellow limestone	17	6	309	9
11	Yellow limestone ...	22	0	331	9
12	Hard grey limestone	5	6	337	3
13	Hard grey limestone, in panels	30	7½	367	10½
	Marl-slate— Ft. Ins.				
14	Soft shale... 0 1¼				
15	Hard shale 1 11¾				
		2	1	369	11½
16	Fish-bed	1	0½	371	0
17	Blue-grey sand ...	75	0	446	0
18	Brown-grey sand ...	17	4	463	4
19	Very hard post-girdle	1	0	464	4
20	Blue shale, with red shale-bands ...	21	0	485	4
21	COAL	0	3	485	7
22	Grey shale	2	5	488	0
23	COAL	4	4½	492	4½
24	Grey post	2	2½	494	7
25	Seggar-clay	11	8	506	3
26	COAL	0	10	507	1
27	Grey shale	5	9	512	10
28	Dark-grey shale ...	2	10	515	8
29	COAL	0	1¾	515	9¾
30	Dark-grey shale ...	0	10¼	516	8
31	Grey post, with blue panels	9	9	526	5
32	Very hard post ...	1	1	527	6
33	Grey post, with shale-partings	12	0	539	6
34	Dark-grey shale ...	0	9	540	3
35	Grey shale	0	4	540	7
36	Post-girdle	0	2	540	9
37	Grey shale	0	3	541	0
	Ft. Ins.				
38	COAL ... 1 5				
39	Stone ... 0 1½				
40	COAL ... 1 10½				
		3	5	544	5
41	Seggar-clay	4	5	548	10
42	Grey shale	3	3	552	1
43	COAL	0	7	552	8
45	Seggar-clay, into ...	...		...	

* *Trans. Inst. M. E.*, 1904, vol. xxviii., page 145.

Table II. records the cribs laid in this shaft, in ordinary and frozen ground. The brine was cut off from this shaft on October 19th, 1905.

TABLE II.—ACCOUNT OF THE CAST-IRON TUBBING IN THE CASTLEREAGH SHAFT, DAWDON COLLIERY.

No. of Crib.	Description of Strata forming the Bed of the Crib.	Depth from Surface. Ft.	Ins.	Remarks.
1	Marl, with gullets	140	2	Water-feeders reduced from 1,520 to 735 gallons per minute.
2	Hard grey limestone ...	184	4	Water-feeders reduced from 4,580 to 380 gallons per minute.
3	Hard grey limestone ...	200	8	Water-feeders reduced from 5,750 to 4,050 gallons per minute.
4	Hard grey limestone, frozen	259	3	......
5	Yellow limestone, frozen ...	319	5	......
6	Hard grey limestone, in panels, frozen	357	0	......
7	Blue-grey sand, frozen ...	390	4	......
8	Blue-grey sand, frozen ...	432	4	......
9	Blue shale, with red shale-bands, frozen	468	4	......
10	Grey shale	510	6	October 9th, 1905.

The "fish-bed," 12½ inches thick, was found at a depth of 369 feet 11½ inches.

The "sand," 92 feet 4 inches thick, was struck on July 22nd, 1905, at a depth of 371 feet, and was sunk through into the Coal-measures on September 2nd, 1905.

During the six weeks occupied in sinking through the sand, the seventh and eighth crib-beds, with their lifts of tubbing, were laid in the frozen sand.

TABLE III.—SECTION OF STRATA SUNK THROUGH IN THE THERESA SHAFT, DAWDON COLLIERY.

No.	Description of Strata.	Thickness of Strata. Ft.	Ins.	Depth from Surface. Ft.	Ins.	No.	Description of Strata.	Thickness of Strata. Ft.	Ins.	Depth from Surface. Ft.	Ins.
1	Soil	1	0	1	0	11	Grey limestone ...	73	4	312	8
2	Clay	5	0	6	0	12	Grey limestone, with large gullets, filled with yellow limestone	23	4	336	0
3	Gravel	3	0	9	0	13	Hard grey limestone	31	0	367	0
4	Marl, with hard limestone-panels ...	6	1	15	1		*Marl-slate*— Ft. Ins.				
5	Marl	22	6	37	7	14	Soft shale ... 0 1				
6	Limestone	6	0	43	7	15	Hard shale 1 3	1	4	368	4
7	Strong beddy marl	66	0	109	7	16	Fish-bed	0	10½	369	2½
8	Strong marl, in blocks	64	8	174	3	17	Sand, into	24	0	393	2½
9	Hard limestone, honey-combed	60	6	234	9						
10	Grey marl	4	7	239	4						

The ninth crib-bed, through the sand, was laid on September 9th, 1905, and the lift of tubbing making the sand secure was completed on September 19th, 1905.

Theresa Shaft.—This shaft had been filled up with marl, concrete, etc., to a depth of 288 feet. Sinking through the concrete was commenced on August 22nd, 1905. The limestone was struck in the shaft-bottom on October 4th, 1905; bore-holes were then put down into the sand, which was found to be frozen hard (Table III., and Plate V.).

Table IV. records the cribs laid in this shaft, in ordinary and frozen ground.

TABLE IV.—ACCOUNT OF THE CAST-IRON TUBBING IN THE THERESA SHAFT, DAWDON COLLIERY.

No. of Crib.	Description of Strata forming the Bed of the Crib.	Depth from Surface. Ft.	Ins.	Remarks.
1	Hard limestone, honeycombed	196	2	Water-feeders reduced from 6,075 to 1,100 gallons per minute.
2	Hard limestone, honeycombed	226	9	Water-feeders reduced from 2,850 to 1,470 gallons per minute.
3	Grey marl	236	5	Water-feeders reduced from 1,560 to 400 gallons per minute.
4	Grey limestone, with large gullets, filled with yellow limestone	327	11	Water-feeders reduced from 1,720 to 380 gallons per minute.
5	Hard grey limestone, frozen...	354	11½	October 18th, 1905.

Prof. H. LOUIS (Newcastle-upon-Tyne) proposed a hearty vote of thanks to the owners of the colliery, and to Mr. V. W. Corbett, Mr. F. Coulson and Mr. E. Seymour Wood for so kindly entertaining them that day.

Mr. B. DODD (Bearpark Colliery) seconded the motion, which was carried with acclamation.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,
DECEMBER 11TH, 1905.

MR. T. W. BENSON, PRESIDENT, IN THE CHAIR.

DEATH OF MR. WILLIAM LOGAN.

The PRESIDENT (Mr. T. W. Benson) said that the members had to deplore the death of a very popular and esteemed colleague, the late Mr. William Logan. He was very well known to the members as an eminent mining engineer and as one who took a great interest in public work. To his more intimate friends he endeared himself by the kind way in which he was always ready to assist the younger members of the profession. He moved that a letter of condolence be sent to the daughter of the deceased gentleman, expressing the great regret of the members at his death, and conveying their sympathy with her in her bereavement.

The vote of condolence was adopted.

The SECRETARY read the minutes of the last General Meeting, and reported the proceedings of the Council at their meetings on November 25th and that day.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. ORMSBY GORE ADAMS, Director, School of Mines, Thames, New Zealand.
Mr. GEORGE AUGUSTUS BURTON, Mining Engineer, Liverton Grange, Loftus, R.S.O., Yorkshire.

Mr. THOMAS LEWIS FRYAR, Engineer to Jondaryan Shire Council, Toowoomba, Queensland, Australia.

Mr. THOMAS HINDSON, Colliery Manager, Framwellgate Colliery, Durham.

Mr. BENNET JOHNS, Manager of Slate-mines and Quarries, Station Road, Keswick.

Mr. EDWARD JOHNSON, Mining Engineer, Redworth Road, New Shildon, R S.O., County Durham.

Mr. JOHN MORGAN, Mechanical Engineer, Stanley Villa, Crook, R.S.O., County Durham.

Mr. ARNOLD CARL LOUIS OLSEN, Mechanical Engineer, Crown Deep, Limited, P.O. Box 102, Fordsburg, Transvaal.

Mr. GLANVILLE REAH, Mining Engineer, 13, Linden Villas, Gosforth, Newcastle-upon-Tyne.

Mr. JOHN ROBERTS, Mine Manager, Laxey, Isle of Man.

Mr. WILLIAM PITT WELTON, Mining Engineer, Glasllyn, Elm Road, Wembley, R.S.O., Middlesex.

ASSOCIATE MEMBERS—

Mr. GEORGE AINSWORTH, The Hall, Consett, R.S.O., County Durham.

Mr. WILLIAM HENRY COPE, The University, Birmingham.

Mr. EDWARD JAMES GEORGE, Beech Grove, Consett, R.S.O., County Durham.

Mr. CHARLES HALL, 196, Gresham House, London, E C.

Mr. JOSEPH HUNTER, Royal Insurance Buildings, Newcastle-upon-Tyne.

Mr. HENRY PICKERING, 13, South Parade, Whitley Bay, R.S.O., Northumberland.

Mr. RICHARD HENRY PRIOR-WANDESFORDE, Castlecomer House, Castlecomer, County Kilkenny, Ireland.

Mr. HENRY WILLIAMS, Llwyngwern, Pontardulais, R.S.O., Glamorganshire.

ASSOCIATES -

Mr. WILLIAM COCKBURN, Under-manager, Railway Terrace, New Lambton, Fence Houses.

Mr. ROBERT CROMBIE, Under-manager, Hollin Hurst House, Rowlands Gill, Newcastle-upon-Tyne.

Mr. MARK HUDSON, Under-manager, 115, Gurney Valley, Bishop Auckland.

Mr. THOMAS JOHNSON, Under-manager, Grange Villa, Chester-le-Street.

Mr. WILLIAM ROCHESTER, Under-manager, 1, Office Row, Netherton Colliery, Nedderton, Newcastle-upon-Tyne.

Mr. ROBERT ROLFE, Under-manager, Felkington Colliery, Norham, R.S.O., Northumberland.

Mr. RICHARD SUMMERBELL, Under-manager, Preston Colliery, North Shields.

STUDENTS—

Mr. ROLLO SAMUEL BARRETT, Student Mining Engineer, Whitehill Hall, Chester-le-Street.

Mr. ROBERT WILLIAM CHURCH, Mining Student, 8, Devonshire Place, Newcastle-upon-Tyne.

Mr. FELICIANO NABLE, Mining Student, 17, Hazelwood Avenue, Jesmond, Newcastle-upon-Tyne.

Mr. ERNEST ARTHUR SMITH, Apprentice Mining Engineer, 3, Bath Terrace, Seaham Harbour, Sunderland.

Mr. RALPH PERCY WILKINSON, Mining Student, Burnmoor Lodge, Fence Houses.

SUBSCRIBERS—

THE HONOURABLE LORD NINIAN EDWARD CRICHTON-STUART, House of Falkland, Falkland, S.O., Fifeshire. *Transactions* and correspondence to be sent to c/o Messrs. J. and F. Anderson, 48, Castle Street, Edinburgh.

Messrs. D. H. AND G. HAGGIE, Sunderland.

SOCIÉTÉ HOUILLÈRE DE LIÉVIN (PAS-DE CALAIS), Liévin, Pas-de-Calais, France.

DISCUSSION OF MR. DONALD M. D. STUART'S PAPER ON "THE DEVELOPMENT OF EXPLOSIVES FOR COAL-MINES."*

MR. DONALD M. D. STUART wrote that, apparently, his paper embodied records not readily accessible, and, therefore, did not offer the usual favourable field for discussion. The figures, however, had been extracted from official documents with great care, and could only be given in the condensed summaries represented by the tables, as the schedules of detail were much too voluminous for a place in the *Transactions*. He thought that there was room for difference of opinion as to the deductions from some of the records, but others scarcely admitted of divergent views. He referred particularly to the following summaries:—Table I.:—Colliery-explosions caused by modern explosives, showing that they had caused explosions not distinguishable from those due to gunpowder.† Table II.:—Fatal and non-fatal explosions caused by shot-firing, showing an increase during the régime of the permitted explosives compared with the antecedent period.‡ Table III.:—Quantity of coal won per gaseous ignition due to shot-firing, showing a yield of, say, 18,000,000 tons during the régime of the Explosives Order compared with, say, 24,000,000 tons in the previous period.§ And Table V.:—Blasting accidents showing increases of 22 per cent. and 30 per cent. in fatal and non-fatal accidents respectively, since the Explosives Order had been in force.||

These facts of experience showed that modern explosives had not fulfilled the anticipations of security from explosions and blasting accidents; but, on the contrary, explosions had increased with their compulsory adoption, increasing the cost in mortalities and mutilations, in winning the production of coal.

* *Trans. Inst. M. E.*, 1905, vol. xxix., page 299; and vol. xxx., page 122.

† *Ibid.*, vol. xxix., page 301. ‡ *Ibid.*, vol. xxix., page 311.

§ *Ibid.*, vol. xxix., page 312. || *Ibid.*, vol. xxix., page 314.

He (Mr. Stuart) found that Mr. H. Hall appeared to question the correctness of the number of fatal explosions in Table II., resting his objection upon the diminished loss of life by explosions in the three decades, 1875-1904, and giving the annual averages of the first and last periods at 256 and 60 lives respectively. These figures evidently referred to explosions from all causes, and the gratifying improvement was obviously due to many changes, including the use of improved safety-lamps and their more general adoption; more perfect ventilation, the substitution of the fan for the furnace, and a better knowledge of the functions of coal-dust in colliery-explosions, with methods for rendering it more or less inocuous. The paper under discussion was limited to explosions by shot-firing, and, while the records confirmed Mr. Hall's observation that explosions had diminished in destructiveness, they did not confirm his opinion that explosions had diminished in number. The official figures for the periods named were:—First decade, 1875-1884, 37 fatal explosions; second decade, 1885-1894, 27 fatal explosions; and third decade, 1895-1904, 32 fatal explosions. The third decade embraced seven years of permitted explosives under the Explosives Order, but it showed a material increase over the preceding period, confirming the deductions from Tables II. and III. of the paper.

He (Mr. Stuart) also noticed Mr. Hall's pertinent question as to how many of the explosions in the six years, 1898-1903 (Table II.), were due to gunpowder; unfortunately, the question could not be answered from the published records, as the information which they contained was imperfect. It was not possible to allocate the non-fatal explosions to permitted explosives and gunpowder respectively from the official records, as the name of the explosive used in the shot that caused the explosion was too frequently omitted. Referring to the 16 fatal explosions, 4 causing 12 deaths were attributed to gunpowder, and the remaining 12 (with 32 deaths) to other explosives; so that 75 per cent. of these explosions were attributed to modern explosives, although they were hedged round with statutory rules as to quality, custody and use; precautions wholly absent with gunpowder.

He (Mr. Stuart) felt some difficulty in understanding Mr. Hall's objection to the deduction in the paper that the diminished

loss of life in explosions was due to arrest of propagation, that was to say, to conditions distinct from the shot or explosive used; or Mr. Robert McLaren's objection on the same point. It was surely obvious that, if the gaseous ignition at the shot occurred under conditions that disallowed its extension into the workings, the only men who could suffer were those in the immediate vicinity of the ignition; but, if the conditions were favourable to extension to other workings, the explosion was propagated to other places, killing the men in these also. The number of lives lost, that was to say, whether the men at the point of origin only, or at more remote places, therefore depended upon the area of propagation, and this area was manifestly independent of the shot or explosive used, and dependent upon the condition of the workings. For example, the explosions at the Apedale and Albion collieries were originated by shots charged with the same typical explosive; in the former 10 lives were lost and 290 in the latter, where there were miles of propagation. Did Mr. Hall and Mr. McLaren suggest that the awful disparity in the loss of life was due to the explosive used in the shots? Or that this disparity was due to any other cause than propagation?

He (Mr. Stuart) agreed with Mr. Hall that copious watering was the practical panacea for propagation of explosions, and urged it many years ago in the publications referred to in the paper, but felt unable to agree with him as to the relative safety of explosives, except in condemnation of inferior gunpowder to which explosions had been traced, and which was still allowed to be used in mines outside the Explosives Order, notwithstanding the powers conferred by the Coal-mines Regulation Act, 1896, to exclude it. He could not resist the conviction that, if high-grade gunpowder (the standard, which surely ought to be made compulsory for every coal-mine in which gunpowder was used) were capable of producing calamities that Mr. Hall thought were too awful to contemplate, the marvellous fact that there had not been such an explosion by a gunpowder-shot since the Seaham colliery calamity five-and-twenty years ago (although in this interval not less than 200,000,000 to 300,000,000 shots had been fired) must be ignored, depriving actual experience of its practical value. Even in the past fifteen years, since the Morfa disaster which was attributed to gunpowder upon doubtful evidence, the most disastrous explosion by a gunpowder-

shot was at Brancepeth colliery, in 1896, with a loss of 20 lives; but, in this same period, there had been the Tylorstown colliery-explosion with a loss of 57 lives attributed to a shot of ammonite; the Albion colliery-explosion with its death-roll of 290 lives, attributed to charges of gelatine-dynamite or gelignite; and recently, the National colliery-explosion attributed to a shot of gelignite, with a roll of 119 deaths, and this, in the opinion of Mr. J. T. Robson and Mr. F. A. Gray, H.M. inspectors of mines, would have been propagated into the Two-feet-nine seam workings containing 606 men, causing a calamity that would have dwarfed all previous explosions, but for the wet condition of the intervening lengths of the shafts.* When these facts were recognized; also, that gelignite and ammonite had passed the original Woolwich test; further, that the latter explosives with many of the same type were still on the permitted list, it was difficult to understand why Mr. Hall offered no objection to these explosives. Even now he spoke of them as "almost flameless," and limited condemnation to gunpowder, to which no explosion approaching that at Albion colliery, had been attributed; surely this was taking a position dangerous to future coal-mining.

He (Mr. Stuart) thought that Mr. McLaren's suggestion that the higher explosives were safer than gunpowder because "none of the higher explosives emitted flame to the same extent as gunpowder,"† was due to a misapprehension of the facts given in the paper; but the facts were recently expressed with such clearness by Capt. J. H. Thomson, H.M. chief inspector of explosives, that he ventured to quote again:—"Flame . . . may be only the glow of incandescent dust, or may be a true flame of burning gases from the explosive. In the former case it may be harmless, while in the latter case it would certainly be capable of igniting gas and even coal-dust. It is not possible to distinguish by eye between the different kinds of sparks and flames, nor is brightness always an indication of high temperature. It is well known that the faint blue flame of a Bunsen burner is much hotter than the bright flame of a gas-lamp. In the same way the invisible gases coming from a shot of an

* *Reports to His Majesty's Secretary of State for the Home Department on the Circumstances attending the Explosion which occurred at the National Colliery, Wattstown, on the 11th July, 1905*, by E. Milner-Jones, Barrister-at-Law, and by F. A. Gray and J. T. Robson, H.M. Inspectors of Mines, page 21.

† *Trans. Inst. M. E.*, 1905, vol. xxx., page 123.

explosive like gelignite, are hotter and more capable of igniting gas than the visible glow given off by bobbinite."* He agreed with Mr. McLaren that it would be very unwise to fire any explosive yielding spark or glow in "an atmosphere of an explosive nature;"† but he would go further, and say that it would be criminal to fire any explosive whatever in such an atmosphere, and a distinct violation of General Rule 12, clauses (*f*) and (*g*).

In conclusion, he (Mr. Stuart) observed that his paper was prepared as a *résumé* of the facts of experiment and experience, and he felt sure that everyone, who took personal interest in the very important subject of minimizing the dangers incident to blasting in coal-mines, would deal with the facts in a purely scientific spirit, and if experience did not support the theory that he had advanced from experiment, he would willingly welcome the discovery, for the purpose of pursuing his quest of the safest all-round explosive for coal-mining.

DISCUSSION OF MR. M. F. HOLLIDAY'S PAPER ON "AN OUTBREAK OF FIRE, AND ITS CAUSE, AT LITTLEBURN COLLIERY."‡

Mr. M. F. HOLLIDAY wrote that he had made the following supplementary experiments with electric lamps of 16 candle-power at 110 volts. The thermometer only registered from 90° to 430° Fahr.:—

Experiment III.—An electric lamp was placed in a can containing 20 ounces of water, at 60° Fahr.; and in 2 hours 20 minutes after the current had been switched on, the temperature of the water had increased to 180° Fahr.

Experiment IV.—An electric lamp was covered to a depth of 2 inches in a pail containing 15¾ pounds of coal-dust (Busty and Brockwell seams) gathered from the disintegrator. In 5 minutes, after the current had been switched on, the coal was smoking. In 9 minutes, the electric lamp exploded, and the hand could not be held near the top of the coal. The coal was on fire at the end of 63 minutes.

* *Memorandum on the Testing of Explosives for Coal-mines and on the Behaviour of the Explosive Bobbinite*, by Capt. J. H. Thomson, H.M. Chief Inspector of Explosives, March 1904, page 2.

† *Trans. Inst. M. E.*, 1905, vol. xxx., page 124.

‡ *Ibid.*, 1905, vol. xxix., page 294.

Experiment V.—An electric lamp was laid on the top of a pail filled with small coal (Busty and Brockwell seams) gathered from the disintegrater. In 7 minutes, after the current had been switched on, smoke was rising. In 20 minutes, the heat was so intense that the hand could not be held within ½ inch of the lamp. In 30 minutes, the temperature of the coal was 330° Fahr. The lamp was removed at the end of 45 minutes. The temperature of the coal where the lamp had been placed, at 50 minutes was 420° Fahr.; at 55 minutes, it had fallen to 385° Fahr.; and at 60 minutes, to 360° Fahr. In 65 minutes, the coal, at a depth of 3 inches, had a temperature of 430° Fahr. And within 85 minutes, the coal took fire.

Experiment VI.—An electric lamp was laid on the top of a piece of ordinary greasy waste. In 2 minutes, after the current had been switched on, smoke began to rise; and in 17 minutes, there was a strong fire.

Experiment VII.—An electric lamp was covered with a piece of flannelette. In 2 minutes, after the current had been switched on, smoke began to rise; and in 3 minutes, the flannelette was charred. In 8 minutes, the material was in flames, and the lamp exploded.

Experiment VIII.—An electric lamp was covered with a piece of cotton. In 4 minutes, after the current had been switched on, smoke began to rise; and in 11 minutes, the cloth was charred. In 31 minutes, the cloth took fire; and in 36 minutes, it was in flames.

Experiment IX.—An electric lamp was covered with a piece of chiffon. In 4 minutes, after the current had been switched on, smoke was seen; and in 15 minutes, the cloth was charred. In 40 minutes, the chiffon was removed from the lamp, as it would not take fire.

Experiment X.—An electric lamp was covered with a piece of white flannel. In 2 minutes, after the current had been switched on, smoke was seen; and in 30 minutes, the cloth was removed as it would not take fire.

Mr. W. Walker (H.M. Inspector of Mines) wrote that the thanks of the members were due to Mr. Holliday for having given them the results of his experience and experiments; for thereby their attention was drawn to the great danger arising from un-

protected incandescent electric lamps and combustible materials being placed in contact with each other; and similar fires would be thus prevented in the future. The danger was probably known to electricians and many others, but the majority of persons employed in and about mines were, undoubtedly, under the impression that electric lamps were absolutely safe under all conditions and in all positions; and, if this feeling of false security were removed, a much desired result would have been attained. It was perhaps surprising that more fires had not been traced to this cause; but it must be remembered that it was extremely likely that some fires, for which it had hitherto been difficult to account, might have been caused in the same way as the dust was ignited at Littleburn colliery.

Dr. P. PHILLIPS BEDSON wrote that, whilst one could not be surprised that coal-dust should be ignited under the conditions set forth, still there could be little doubt that coal-dust in contact with an electric lamp must have acquired a higher temperature than 150° Fahr., before it ignited.* Some years ago, Prof. Henri Fayol, in his work on the spontaneous inflammation of coal, shewed that the temperature of ignition of coal-dust was 356° Fahr. (180° Cent.),† and in the report on the explosion of the air-receiver at Ryhope colliery in 1883, he (Dr. Bedson) had described experiments in which he had successfully ignited coal-dust heated in an air-bath at the lowest recorded temperature of 284° Fahr. (140° Cent.):‡ a temperature which must have been readily reached by the coal-dust surrounding the incandescent electric lamp in the experiments described by Mr. M. F. Holliday.

Mr. J. B. ATKINSON (H.M. Inspector of Mines) quoted the following passages, written by his brother (Mr. W. N. Atkinson) and himself, some years ago:—

The coal-dust collecting on the higher parts of the haulage-roads appears to undergo some change, and becomes more readily combustible than fresh coal-dust. Thus, the writers have found that upper dust collected from dry collieries in the North of England has the property of burning *en masse*; that is, if flame

* *Trans. Inst. M. E.*, 1905, vol. xxix., page 295.

† "Étude sur l'Altération et la Combustion Spontanée de la Houille exposée à l'Air, by Mr. Henri Fayol, *Bulletin de la Société de l'Industrie Minérale*, 1879, series 2, vol. viii., pages 487, 490 and 621.

‡ *Trans. N. E. Inst.*, 1888, vol. xxxvii., page 211.

is applied to it so as to heat a small portion to redness, combustion gradually spreads itself through the mass, no flame being visible. Ordinary coal-dust has not this property. Upper dust would appear to have undergone some chemical or physical change. It is possible that absorption of oxygen from the air may have taken place.*

The inflammable nature of dust on the roadways of collieries is well known, and has been the cause of several fires. The dust has been ignited by a shot, or by the "snot" from a lamp being thrown amongst it. In some collieries, nothing but safety-lamps are allowed to be used on the haulage-roads, in order to prevent the ignition of the dust.†

Mr. Holliday had performed a very useful task in calling attention to the danger arising from the use of incandescent electric lamps. At first sight, one would have thought that it was a perfectly safe light for use in mines, but the ready inflammability of coal-dust, particularly the very finest which collected in the upper parts of the roadways, was a dangerous element in connection with these lamps.

Mr. W. C. Blackett thought that a word might be said from the other side. Members had expressed their surprise that they had not known before that incandescent electric lamps could create so much heat. Personally, he was equally surprised that a member could conceive anything to the contrary, for it must be evident that the filament, at a white heat, placed so near to the outside of the lamp, must impart a great deal of heat to whatever was near to it. Only the other day, a fitter laid an incandescent electric lamp on a carriage-cushion, and, in a very short time, it was burnt through and destroyed.

Mr. C. C. Leach said that the only experiment that he had made with an incandescent electric lamp was to take hold of one, and he was glad to remove his hand speedily.

Mr. A. Andrews said that, no doubt, there was much want of thought shewn on the part of some people who used electric lamps. Only the previous week, he saw an electric lamp placed upon a creosoted prop, and he pointed out that the prop would speedily take fire. He was informed that they had no idea that an incandescent lamp would cause fire. He suggested that the bulb might, with advantage, be enclosed within another globe for use in places where there was any risk of fire.

* *Explosions in Coal-mines*, 1886, by Messrs. W. N. and J. B. Atkinson, page 21.

† *Ibid.*, page 22.

Mr. W. C. Blackett said that Mr. Holliday mentioned that an electric lamp burst on being enclosed in coal-dust, but he (Mr. Blackett) believed that this was not quite correct. He thought that the lamp would not burst, but that it would collapse. He had seen the glass of an incandescent lamp bulge inwards without collapsing.

Mr. T. E. Forster said that, when electric lighting was first adopted in collieries, it was always the practice to enclose the bulb in an outer casing. It was only after a number of years that some dispensed with the outer cover, and now many of the members seemed to be surprised that an electric lamp placed on cotton waste would ignite it.

Mr. C. C. Leach suggested that the outer casing was dispensed with, because it now cost more than the lamp.

Mr. H. Lawrence said that the heat of an electric lamp was accumulative, and ultimately it was sufficient to set fire to the coal-dust. It appeared that engineers had grown so accustomed to the use of electric lamps that they were somewhat astonished to find that they constituted a grave danger with coal-dust, but the members must not be too ready to attribute fires to the electric lamp. The topic was a very interesting one, and required further discussion for the benefit of mining engineers and coal-owners.

Mr. Sydney F. Walker (Bath) wrote that the further experiments, which Mr. Holliday had carried out, were of great interest, principally, as he understood the matter, because they showed that the heating effect in the coal-dust was largely due to oxidation. There appeared to be two distinct operations: firstly, heat was communicated by the lamp to the coal in its immediate neighbourhood; and secondly, at a certain temperature, oxidation of the carbon in the coal was set up, leading to a further and much larger liberation of heat. This was clearly shown by the results of the third and fourth experiments, in which the quantities of water and coal heated, as well as the times, were given.

In the third experiment, 20 avoirdupois ounces of water, raised from 60° to 180° Fahr., would absorb 150 British thermal units. A 60 watts, 16 candlepower lamp received 3·45 heat-units per minute, and a 50 watts lamp, 2·8 units per minute. In the two

hours during which the experiment continued, a 60 watts lamp, therefore, would receive 514 British thermal units, and a 50 watts lamp, 336 units; as only 150 units remained in the water, the other heat-units were evidently lost by radiation and convection. If the can had been enclosed within a good thermal insulator, the water would have been raised to a much higher temperature in 2 hours, or if 180° Fahr. had been determined upon as the limit, that temperature would have been attained in about one hour with a 50 watts lamp, or in about 45 minutes with a 60 watts lamp.

In the fourth experiment, there was a very different state of things. Taking the specific heat of coal at 0·377, the ignition-point of coal at 356° Fahr., and the initial temperature of the coal (for convenience in calculation) at 56° Fahr., the heat delivered to the coal (if the whole mass were at ignition-temperature) would be 1,781 units. As the lamp was only left in contact with the coal for 63 minutes, the total heat delivered by the lamp in that time, would be, with a 50 watts lamp, 176 units, and with a 60 watts lamp, about 214 units. Hence, there must have been another source of heat available, and this would be the oxidation of the coal, which would possibly increase with the temperature.

The remaining experiments on different materials were also of considerable interest, though they merely confirmed what was already known, with reference to some of the materials, while they apparently gave flannelette a better character than it had received from the general public. In Mr. Holliday's experiments, it took 8 minutes to produce flame with flannelette, while greasy waste took 17 minutes, and cotton 31 minutes. The general idea had been that flannelette would burst into flame instantly.

Prof. Henry Stroud (Armstrong College) wrote that, as the ordinary method of producing light is by raising a substance, such as the carbon-filament of an incandescent electric lamp, to a very high temperature, one must, therefore, not be surprised that heat is produced in connection with that source of light. In some of Mr. Holliday's experiments, such as the first, where the lamp was covered with coal-dust, practically all the energy expended in the lamp was absorbed by the coal-dust; and it was only a question of time, as Mr. S. F. Walker had pointed out,

before ignition must occur. Ordinarily speaking, the incandescent electric lamp was perfectly safe, but when absorbent materials were placed near the lamp, danger of course might arise. Even in the ideal case of producing light, in which the luminous radiation was obtained without any proportion of non-luminous, such as the glow-worm practically accomplished, the luminous radiation when absorbed produced heat.

There could be no doubt that Mr. Holliday's paper and experiments would do a large amount of good, by reminding members who used incandescent lamps, of the dangers that might arise if it were supposed that the radiation of the lamp could not, by its absorption, produce heat. At the same time, it would be unfortunate if the impression were produced that there was any danger of fire, in the slightest degree, when an electric lamp was used with ordinary care, due attention being paid to the general phenomena of heat.

Mr. M. F. Holliday, replying to the discussion, wrote that Dr. P. P. Bedson's remarks as to temperature were quite correct. The instrument used in the first and second experiments was incorrect; and, as shown in the fifth experiment, the temperature acquired by the coal-dust varied from 350° to 400° Fahr.; and he had no doubt that the same temperature obtained in the first and second experiments.

He (Mr. Holliday) was positive that the lamps were burst in the first and seventh experiments, as the fragments of the lamps were thrown outwardly; and if the lamps had collapsed, as Mr. Blackett suggested, this could not have taken place. He, therefore, adhered to the assertion that "the lamp exploded."

DISCUSSION OF MR. G. C. WOOD'S PAPER ON THE "DETERMINATION OF THE SPECIFIC ELECTRICAL RESISTANCE OF COAL, ORES, ETC."*

Mr. P. Kirkup (Birtley), with regard to his remarks at the previous discussion on this paper, wrote that it might be of interest to members to have the full facts of the case there quoted. The cement-floor had the following composition:—Crushed common red brick, 36 per cent.; ordinary fire-brick, 36 per

* *Trans. Inst. M. E.*, 1905, vol. xxx., page 99

cent.; and pure cement, 28 per cent. The switchboard was made of first-class slate, so far as purity was concerned, but of rather a soft nature, 1 inch in thickness, and the distance between the live or contact parts of the switch was 5 inches. The fact that the attendant, when handling the switch-gear, received a severe shock proved that: (1) Although under extremely dry conditions, such as might be found in a generating-station, where the conditions are such that the concrete would soon be freed of all its moisture, concrete of the above composition might be regarded as a safe insulation. But, situated underground, where the concrete was built on a damp floor and was itself composed of a very porous material, and where there was no artificial heat to expel the moisture that was certain to be present in the concrete, it was evident that concrete could not be depended on as an insulator. (2) Even the good normal slate on which switch-gear were mounted could not be said to be a perfect insulator, under the damp conditions usually found in underground workings.

He (Mr. Kirkup) had found that samples of concrete, tested on the surface, gave excellent records of insulation resistance, and that concrete of exactly the same composition had, after having been underground a short time, given quite a reverse record: the insulation having partially broken down.

All the current-carrying parts of the switch-board, after the shock mentioned was received, were bushed with ebonite, and this practice was now being carried out throughout the collieries under his charge. Porcelain was being largely utilized for the same purpose; and some makers were using iron as the material for the switch-boards, and the current-bearing parts were bushed with porcelain.

Mr. H. W. G. Halbaum's paper on "The Great Planes of Strain in the Absolute Roof of Mines," was read as follows:—

THE GREAT PLANES OF STRAIN IN THE ABSOLUTE ROOF OF MINES.

By H. W. G. HALBAUM.

Introduction.—In a recent paper,* dealing with the roof-phenomena in normal longwall mines, it was premised that the force of the total roof-action was the oblique resultant of two components: the one acting vertically downwards, and the other acting horizontally and contrary to the direction of working. The line of action being thus defined, it was inferred that the line of reaction upon the roof itself was of equal obliquity but of opposite direction. It was therefore averred that the principal planes of fracture (incipient or developed) in the roof, viewed from the mine below, must be projected over and towards the solid like the hade-lines of faults having their upthrows in the direction of working. Proof of these fundamental propositions was not tediously laboured, the writer regarding them as postulates, the axiomatic character of which would be readily and generally granted, as undisputed premises, in fact, from which conclusions might be safely deduced, and by means of which the phenomena might be satisfactorily accounted for and explained, or even predicted.

Subsequent discussion, however, showed that the writer had been rather too sanguine in this respect; and what he had considered as an unexceptionable lemma was regarded by others as an original proposition requiring much proof. The theory, however, clearly explained and accounted for many roof-phenomena which would otherwise be most inexplicable. In order to meet certain objections which have been made, therefore, the writer now proposes to justify, if possible, the premises adopted in his previous paper and re-stated in the opening paragraph of the present contribution. The existence of a vertical force in roof-action will be questioned by nobody. The object and scope of this paper are made sufficiently plain by the mere statement of

* "The Action, Influence and Control of the Roof in Longwall Workings," *Trans. Inst. M. E.*, 1904, vol. xxvii., page 205.

the following proposition: Contained in the total force of the roof-action, there is a horizontal component, the action of which is contrary to the direction of working, and the power of which is sufficient to deflect the roof-action from the vertical line. If this proposition can be maintained, the validity of the entire theory previously propounded follows as a matter of course. The proof herewith submitted is of the cumulative type.

Definitions of Terms.—The following terms are employed and defined, in order to secure clearness of idea and brevity of expression. "Mined strata" form that sub-cylindrical column of strata the perimeter of which is that of the excavation proper. "The dead zone" is that portion of the mined strata which has settled through the maximum subsidence. "The motive zone" is that portion of the mined strata which, being still in process of sinking, goes far to furnish the motive power producing the phenomena. "The littoral zone" embraces the disturbed strata lying immediately outside the sub-cylinder of mined strata. "The prime strata" are the strata beyond the littoral zone, and as yet absolutely undisturbed by the action of the motive zone. "The absolute roof" is the entire body of overlying strata. "The nether roof" is the immediate roof of very limited depth such, for instance, as timber might be expected to support. "The vertical face" is the vertical plane of the line of working-face in longwall, or that of the goaf-line in bord-and-pillar systems. This vertical face is the conterminous face of the motive and littoral zones. "The prime face" is the face of the prime strata, or the conterminous face of the littoral zone and the prime rocks *in situ*. "Forward," "backward," "behind," "beyond," etc., are to be construed with reference to the direction of working, which is "forward," and at right angles to the vertical face. "Resilience" is the elasticity of traction and pressure. "Stress" is intensity of force. "Strain" is any alteration of figure produced by the application of force.

The Draw.—The term "draw" is associated with a subsidence of the littoral zone as observed at the surface. The draw itself is simply a measurement across the littoral zone of subsidence and is taken at right angles to the vertical face, but the term is sometimes used as the name of the essential disturbance

with which it is associated. In this paper, the essential disturbance itself will be called the littoral disturbance, and the term "draw" will signify the measure abovenamed. In the writer's view, the draw is simply the distance by which, at the surface, the vertical face and the prime face are separated. In other words, it is the surface-width of what is herein called the littoral zone (Fig. 1, Plate VI.).

A certain paper,* published nearly twenty years ago, may be referred to. Mr. J. S. Dixon carried out a series of experiments extending over a period of two or three years. It was demonstrated that the wave of maximum subsidence (the forward limit of the dead zone) regularly followed the advancing face at a stated distance; and not only so, but also that the wave of littoral disturbance was just as regularly projected in advance of the vertical face. Whilst the vertical face advanced, the littoral disturbance continually preceded it; and when the further advance of the face was arrested for good, the littoral disturbance also ceased to project its forward limits. The positive draw varied from 83 to 100 feet, and the relative draw from about one-eighth to two-thirteenths of the depth from the surface.

In two other cases mentioned more recently by Mr. J. P. Kirkup,† the draws extended from 66 to 200 feet, representing from about one-fourth to one-third of the depth from the surface. Mr. Kirkup, moreover, alludes to the fact that in one case the subsidence was inappreciable, although the draw was considerable. This observation is very suggestive, and yet it is precisely what the theory of the former paper would lead one to predict. The draw evidently represents an excess of area in the surface-subsidence beyond the area of the excavation proper; and, whatever the subsidence may gain in area at higher horizontal planes, it must correspondingly lose in the matter of depth. Where loss of depth and increase of perimeter are observed on higher planes, it can only be inferred that the whole volume of subsided strata approximates to the shape of an inverted conic frustum; and this is perfectly in accordance with the theory of planes of strain which project over and towards the solid (Fig. 2, Plate VI.).

* "Some Notes on Subsidence and Draw," by Mr. J. S. Dixon, *Trans. M. I. Scotland*, 1885, vol. vii., page 224.

† *Trans. Inst. M. E.*, 1904, vol. xxviii., page 320.

The foregoing authoritative figures furnish practical examples of draw as measurable by the methods of the surveyor: the absolute draws are possibly somewhat greater; but, in any event, the well-ascertained fact of draw at all obliges one to look upon the littoral zone as a zone of disturbance—at least so far as its surface is concerned.

The Under-draw.—It is a matter of common observation (where observation is possible) that the coal-bed adjacent to the face-line (or goaf-line) is less than its normal thickness. The descent of the roof on the coal-stratum is a maximum at the face-line, and runs out to nothing at some little distance beyond that line. The measured distance of this zero-point from the line of face may be called the "under-draw." Just as the draw measures the visible disturbance across the surface of the littoral zone, so the under-draw measures the visible disturbance across the base of the zone; namely, at the level of the coal-stratum. The absolute under-draw, again, is possibly greater than the measurable quantity. This thinning, or compression of the coal cannot be easily demonstrated in a system of longwall-advancing, but it may be readily observed in a system of longwall-retreating, and in the second working of a bord-and-pillar system. In both of these latter systems, the under-draw is probably greatly extended by reason of the greater intensity of roof-pressure sustained, and by reason of the excessive lateral freedom enjoyed by the coal: both of these in turn being due to the cutting-up of the seam by the roads and cross-roads made in the first working. In a system of longwall-advancing, however, we cannot see into the uncut ground beyond the face-line, and therefore we cannot observe the length of under-draw normal to that system. We may be very sure, however, that actual under-draw obtains even here; although, on the other hand, we may be equally sure that the under-draw here obtaining is very much shorter than that observed in the two other systems mentioned. The difference is one of degree (probably of considerable degree), but still one of degree only. That absolute, if not actually measurable, under-draw exists adjacent to the face-line of even a system of longwall-advancing is proved by the changed economic condition, if not by the visibly altered form of the coal at the face, which is now easier to work than when the face was in process of formation

near the shafts. From the fact of draw at the surface, and from that of under-draw at the base, it is therefore inferred that the entire littoral zone has moved bodily (never mind how much) from its original place *in situ*. And if it has moved bodily by ever so small a distance from its place *in situ*, whilst the prime strata at ever so great a distance remain absolutely *in situ*, there must be a deformation of figure produced in each stratum of the absolute roof, and that deformation of figure is essentially associated with what the engineer calls "strain."

The Plane of Elementary Strain.—We may now take, at right angles to the vertical face, an imaginary section of the littoral zone. This section will be a figure of not less than four sides:—(1) The top horizontal line is furnished and measured by the draw; (2) the bottom horizontal line is the line of under-draw; (3) a third line is the profile of the vertical face; and (4) the fourth line is either a straight line or a composite line, and it is furnished by the profile of the prime face. If the absolute dimensions of the draw and of the under-draw were known, it is evident that the mean path of this fourth line could be determined. But whatever be its mean path, it is perfectly clear that it is a line of strain, for it lies in the prime face, that is to say, in the conterminous face of the littoral strata which, by hypothesis, are strained, and of the prime strata which are not. It is a line of strain, for it lies on the face of the littoral strata; it is a line of initial or elementary strain, for it lies on the very face of the prime strata. Moreover, it must presently become a line of principal strain, since it is already become a line of reduced resistance, along which every subsequent application of force will seek to act, as the face of work advances. Here, then, is the elementary line of strain which may or may not eventually become a line of actual fracture according to circumstances. This profile of the prime face may be referred to as the "elementary line" (of strain); and the prime face itself is in reality a plane of strain or incipient fracture. What is now wanted is some kind of evidence with respect to the direction of this line. Is the elementary line a vertical line, a composite line, or what?

Improbable Verticality of the Elementary Line.—It is improbable that the elementary line is a vertical line. Because,

(1) it can be vertical only on the supposition that the entire roof-action is exerted only in the vertical line; and this, in turn, can be a mechanical truth only on the further condition that the vertical force of gravity on a longwall-face is hemmed in on all sides by lateral resistances, which are absolutely equal. It will presently be shown that such is not the normal case, although it may occasionally form an exception to the general rule. And (2) the practical common-sense deduction from absolutely vertical lines of strain and eventual vertical planes of fracture is surely that they would make any moderately clean system of coal-extraction an economic impossibility. Consideration of the weight of strata overhead and of the strength of pit-timber shows that miners must always be largely dependent on side-thrust for the main support of the absolute roof, and this efficient side-thrust can only be generated when the great lines of strain and principal planes of fracture make an angle with the vertical. No one really believes that any wooden prop or any system of timbering can sustain either the dead or the live load of the absolute roof. On the contrary, it is a matter of frequent experience that the roof will subside bodily at a sluggish rate, that can neither be delayed by the setting of props nor accelerated by their removal. As pointed out in the previous paper, the office of the timber is merely to conserve the comparative integrity of the nether roof, and its efficiency is established when it performs this office successfully. All of which irresistibly leads to the inference that the great lines of strain in the absolute roof are deflected from the vertical by angles which throw the bulk of the weight either back on the packs and dead strata, or forward against the face of the prime strata. But if, from any abnormal cause, they swing into the vertical line, the results are vertical slips of strata which may either smother the face of work, or superinduce those violent, though happily rare phenomena known as "bumps," outbursts of coal, liberation of large volumes of gas, with possible explosions of fire-damp, and wholesale disaster to life, limb and property. Such, at least, is the opinion of the writer, not that he supposes "bumps" and their coincident phenomena to be invariably due to vertical slips of strata, but that he believes such slips to be entirely competent to produce such effects. Sudden slips of the absolute roof, or of a portion thereof are unquestionably most liable to

occur when the lines of roof-strain are vertical; and that such slips are of rare occurrence in mining experience is, in the writer's view, strong presumptive evidence that the normal elementary line is not a vertical line. A vertical elementary line is an abnormal line, and produces abnormal phenomena.

Obliquity of the Elementary Line.—In this instance, there are two conceivable cases of obliquity. Although in either case the oblique line will probably make a less angle with the vertical than with the horizontal line, it seems more convenient to take a horizontal datum. Thus, we may conceive that the elementary line either rises or dips (at a large angle) in the direction of working. If it rises, it is an ascending line, its angle is a superior angle, and its obliquity will be considered normal. If the elementary line dips in the direction of working, it is a descending line, its angle is an inferior angle, and its obliquity will be considered as reversed (Fig. 3, Plate VI.). What we now have to consider is whether there are any factors capable of creating either or both of these obliquities.

The Horizontal Motive Force.—If the elementary line be oblique, there must of physical necessity be some horizontal force which is able to deflect the force of gravity from the truly vertical line. In the former paper, the writer alluded to the fact that strata *in situ* were in a state of high compression, and suggested that a horizontal force was set up by the relief of this compression. That idea did not appear to meet with the absolute approval of the members. Yet it appears to the writer to be thoroughly sound. If we take a block of sandstone, say 1 cubic foot, and if we subject this block to a total pressure of 100 tons, are we to infer that the block suffers no strain? And if this pressure be removed, can we imagine that there will be no sensible relief from compression? Yet it is very possible that this same block was subjected to much greater compressive forces *in situ*, not merely by reason of the weight of strata under which it lay buried, but also by reason of the lateral forces which have from time to time crumpled and folded the crust of the earth like so much tissue-paper. Is the earth not still a cooling body? Are slow subsidence and elevation of the land only ancient, or are they also modern natural phenomena? There have been no

violent geological phenomena in the North of England for ages (so far as the writer knows), but are we to suppose that the compressive forces due to the secular cooling of this part of the earth have been suspended and inactive during that time? Have the forces which caused the thrust-planes of Scotland absolutely ceased to exist? Have the forces which produced the cleavage-planes in the coal-seams of Northumberland and Durham left the strata in a state of high compression or not? Is resilience a property of metals only? The writer has heard Prof. H. Louis speak of the flexible sandstones met with abroad, and Prof. Ganot, in his *Elementary Treatise on Physics*, proclaims the resilience of sandstone to be less than that of whalebone by 10 per cent. only. The writer, in face of these facts, cannot but believe that the relief of high compression in mining strata provides a reservoir of horizontal force sufficient to impart the obliquity of the ascending line of strain.

The case of "creep" is homely but suggestive. If there is no real horizontal motive force, creep is an effect without a cause. For creep means either the true horizontal extension of strata, or else it means the bodily translation of matter in the horizontal plane. In creep-phenomena, all agree, however, that force is actually transmitted from beneath the under-draw to the floor of the mined area. Speaking broadly, this force is derived from the weight of the littoral strata which, compressing the strata below the under-draw, either crushes them, or else transmits a lesser stress which obliges them to extend themselves horizontally towards the mined area. If the crushing stress be applied (as many engineers appear to think), the crushed rock must be forced, after the manner of a semi-fluid, across the face-line, and under the floor of the mined area, which is thereupon forced upward to make room for the transported débris. If, on the other hand, the force merely extends these strata horizontally, without "crushing" them, they will extend themselves along the line of least resistance, namely, towards the mined area, where the result, as before, is the bursting of the floor-stratum. The creep must certainly be explained on one or other of these hypotheses. But which? A moment's reflection will show the absurdity of any idea which assumes the force to transmit a stress sufficient to crush the strata in question. For whatever the stress transmitted, it must of necessity be trans-

mitted through the coal-stratum: a stratum enjoying lateral freedom. The ultimate resistance of the coal to crushing is less than that of the rock below, and, obviously, the coal cannot transmit any stress greater than its own crushing stress without being itself destroyed in the process. But since the coal is not destroyed, we know that the strata below are not crushed. The creep, therefore, is due to the true lateral extension of the strata beneath the under-draw. And this lateral extension is due, evidently, not so much to the vertical force transmitted through the coal-stratum as to the pre-disposition (induced by super-compression *in situ*) of the strata to extend themselves in the horizontal plane. You cannot break rock with a hammer whose head is formed of coal, neither can you transmit crushing stresses to rock through a coal-medium enjoying lateral freedom.

And, after all, it requires no heroic credulity to believe in the existence of a practical horizontal motive force. Very small factors may deflect the force of gravity from the normal vertical line. Although this force undoubtedly acts in the truly vertical line, it is well known that the motion, ostensibly due to gravity, may take place along a line distinctly oblique unless the vertical force be hemmed in on all sides by horizontal resistances which are absolutely equal. Any excess on one side becomes a factor of deflection, and, indeed, it is postulated of all forces whatever that they will seek to act along the line of least resistance. Hence, wherever there is a region of greater resistance contiguous to a region of lesser resistance, we obtain an effective motive force the magnitude of which is equal to the difference of the resistances, and the direction of which is from the region of greater towards the region of lesser resistance. To recognize a horizontal motive force, therefore, is merely to recognize a difference of horizontal resistances. Such a force causes a bore-hole to swerve from the vertical line in which the rods are directed. By means of a rotary machine, we can drill a hole through a block of stone, but we cannot drill a groove on its surface. A vehicle runs downhill on ever so slight a slope, in obedience to gravity, yet the horizontal component of the motion is far greater than the vertical component. The horizontal component is due to the difference of the horizontal resistances; in other words, to the horizontal motive force. And the same kind of force causes the motion of the disturbed roof-strata at a long-

wall face to be deflected from the vertical and towards the region of lesser resistance. This region of lesser resistance is obviously furnished by the excavation and its superjacent shaken strata; the region of greater resistance being furnished and occupied by the prime strata beyond the littoral zone. It is also quite obvious that the motive zone must, owing to the force of cohesion, exert a continuous pull on the littoral zone, backward into the mined area.

Can anyone indicate any force that neutralizes this pull? Or can anyone name an opposite force that neutralizes the horizontal motive force due to the abovenamed difference of horizontal resistances? Unless such opposite forces can be very clearly shown to exist, it may be confidently asserted that the action of the roof is downward in obedience to gravity, and backward in obedience to the horizontal motive force. But if the line of the roof-action be downward and backward, the line of reaction on the roof itself must, of physical necessity, be upward and forward; and hence the elementary line of strain is an ascending line which projects over and toward the solid.

So far as any general case is concerned, the writer is unable to believe that the horizontal motive force ever acts in the direction of working, and hence he is unable to believe that the elementary mean line is a descending line of reversed obliquity. Nevertheless, it must be admitted that this idea probably represents the popular conception. Mining engineers commonly say that the roof "arches itself." But they never stop to enquire why it does so; nor do they consider whether the arching process represents much or little in the whole series of phenomena, or whether it extends to the absolute roof or is confined to the nether roof. Let us, however, study the case briefly. Here is an old road used as a return airway. It will arch itself, whether it runs in the same direction as the working or at right angles thereto. Why? Simply because the roof of the road is a bridge across the road: a beam supported at both ends. Below the neutral surface, all the strains in the strata are tensile; above, all are compressive. When the bridge collapses, the roof arches itself. The widest portion of the arch is at the roof-line where the tensile strain is greatest; and the apex oi the arch is at the neutral surface or near it, where the strains are a minimum (Fig. 4, Plate VI.). The so-called arching of the roof, there-

fore, merely illustrates the fact that the greater stresses propagate their strains further than the smaller stresses propagate theirs. This is true for this particular case, and in a subsequent section it will be shown that it is also true for the wider case. Observations of roof-arching are confined to the nether roof, no one has ever observed that it takes place in the absolute roof. If it did, there would probably be no such manifestation as surface-subsidence, and certainly no such phenomena as those associated with the draw. The arching of the nether roof is a very superficial process: the evidence for the great horizontal motive force which deflects the action of the absolute roof must be sought for in the study of more massive phenomena.

The Action and Influence of Unstable Strata.—It has been suggested that any attempt to generalize on the probable character of strain-lines in the absolute roof must be attended with almost insuperable difficulty, owing to the presence therein of subsoils, clays, gravels, sands, etc. If such an objection could be sustained, it would be little use proceeding any further with this enquiry. The case of these unstable strata, therefore, will now be examined.

There are evidently four conceivable cases of unstable strata in the roof: (1) Where the whole of the unstable strata are superjacent to the whole of the firmer strata; (2) where the whole of the unstable strata are subjacent to the whole of the firmer strata; (3) where the unstable and stable strata are interstratified; and (4) where the entire absolute roof consists of unstable strata. The last case appears to furnish the key to all.

If the whole absolute roof is formed of unstable strata, the whole mass will tend to slide downwards on its angle of repose; that is to say, on a plane or planes of fracture, which, according to common knowledge, invariably project over and towards the solid or prime strata; planes of fracture or separation which never by any chance overhang the excavation. Hence, in this case, the area of subsidence as measured on the surface will exceed the area of the excavation as measured below.

Again, if the whole of the unstable strata are superjacent to the whole of the firmer strata, the alleged difficulty vanishes by merely recognizing that in the absolute roof we have a natural bridge of rocky strata bending, not only by reason of its own

huge weight, but also by reason of the load of unstable matter which nature has distributed uniformly along its entire length. Now, in any case of this kind, whilst we are bound to take into account the weights of the bridge and its load combined, it will evidently be sufficient for all practical purposes to investigate the strain of the bridge only: it being seldom necessary to investigate the strain of the load. But supposing the bridge of firm strata to collapse, it is evident that the now unsupported matter of the unstable strata above will immediately slide on its angle of repose, and the area of subsidence as measured on the surface will again be greater than the area of the excavation below.

Yet again, let the whole of the unstable strata underlie the whole of the firmer strata. Then the nether roof and the whole of the unstable matter will tend to slide downwards on its angle of repose, leaving the bridge of superjacent firm strata (let us suppose) *in situ* for the time being. For one moment let us study this bridge. Since the fractured edges of the subsided loose stratum slope away from the excavation below, the bridge must span a wider but somewhat shallower chasm than that due to the excavation proper. Then again, this bridge of rocky strata reposes on the yielding piers furnished by the broken and unstable stratum below. Hence, when the bridge finally collapses, it will in all probability fracture on the heads of its piers rather than at those faces defined by the angle of repose appropriate to the subjacent unstable stratum. That is to say, the yielding character of the piers on which the bridge reposes entitles us to believe that the bridge itself will propagate its strains further in the direction of the prime strata than would be the case if the piers were firmer. Hence, whether we consider the strains of the unstable stratum itself, or those which it superinduces in the rocky bridge above, we still get an area of subsidence which continually extends itself as viewed on higher and higher horizontal planes.

Finally, let it be supposed that the unstable strata of the absolute roof are repeatedly interstratified with the firmer strata. This is but the repeating form of a case already alluded to. That was the case of a rocky bridge of strata carrying a uniform load of unstable strata. This is the case of a series of such bridges superposed one above another in the absolute roof. Then

taking the roof-strata in ascending order, it appears clear that as each firm stratum collapses, the unstable superstratum will slide on its angle of repose, and also superinduce the propagation towards the solid of the strains in the firm stratum next above (as described in the previous paragraph). And so the repetitive phenomena proceed to the very surface, each succeeding stratum, whether stable or unstable, propagating its strains further toward the solid than did the stratum below, and each, as it gives way, continually enlarging the area of subsidence. Thus the whole volume of subsided material finally assumes the approximate shape of an inverted conic frustum, whose lower and smaller radius is x, and whose upper and larger radius is equal to $x+y$; where x is the radius of the excavation proper, and y the length of the surface-draw as measured across the littoral zone.

On the one hand, therefore, it appears to the writer that the presence of unstable strata in the absolute roof tends to simplify rather than to complicate the problem of roof-strains; whilst, on the other hand, the study of such unstable strata tends entirely to fortify and establish the position postulated in the former paper. For, evidently, the influence of unstable strata in the mine-roof is invariably to throw the mean strain-line over and towards the prime strata.

The Cantilever Idea and its Corollary.—It has been suggested that the conception of an ascending line of strain projecting over and towards the solid is incompatible with the idea of a cantilever-action of the roof-strata. So far from being able to accept this view, the writer thinks that the one idea is the natural corollary of the other. It is, perhaps, generally agreed that the action of the absolute roof is that of a cantilever whose load consists primarily of its own huge weight. If this be so, the cantilever will be like other cantilevers in certain particulars. For instance, it possesses a neutral surface. Above this surface all the stresses in the beam of strata are of the tensile order; below it, all are of the compressive order. The uppermost tensile stress and the lowermost compressive stress are the maxima of their respective orders; and both orders of stress regularly diminish as the planes on which they act approach nearer to the neutral surface, at which plane both kinds of stress are reduced to zero.

Other things being equal, the magnitudes of the strains vary as the magnitudes of the stresses that produce them. So far, however, as the great bulk of the absolute roof is concerned, it is commonly held that these strains seldom or never result in fracture. Fractures (it is believed) extend through but a few feet of the lower roof, the greater bulk of strata being strained to some point below the point of fracture. Now, so long as actual fracture is avoided, the strain is propagated; and the magnitude of the stress is reflected in the distance to which the strain is propagated. Thus, when the roof of a road (supported at both sides) collapses, the roof arches itself, and the wider parts of the arch occur where the tensile stresses are greater. And speaking generally, it may be stated as a truism that the greater the stress in any given plane, the greater will be the distance through which the resultant strain is propagated towards the solid.

Thus, in the cantilever of roof-strata, seeing that the maximum compressive stress obtains at the roof-line, the strain in the immediate roof-stratum must be propagated further towards the solid than the strain in the stratum next above will be propagated. The compressive stress in the third stratum is again less than that in the second, and the strain is propagated to a distance which again falls short of that obtaining in the stratum below; and so on, till we arrive at the neutral surface where stress and strain alike vanish. So far as the lower roof is concerned, then, it tends to arch itself, but in this instance, the arching is due to the difference of compressive stresses and to the difference of the distances through which the compressive strains are propagated.

Similarly, above the neutral surface; as we ascend, the tensile strains on successive horizontal planes are, owing to the increasing magnitudes of the tensile stresses, continually propagated further and further in the direction of the solid until, at the terrestrial surface, we find the maximum propagation of tensile strain along the line of the draw. Here, again, we find that the upper roof arches itself in obedience to the differential tensile stresses in the cantilever, but the arch is now an inverted one.

Hence, viewed from the plane of the neutral surface of the cantilever, all the lines of tensile strain finally abut against a plane of normal obliquity, which projects over and towards the solid. And, viewed from the same standpoint, all the com-

pressive lines of strain below finally abut against a plane of reversed obliquity which dips under the solid strata beyond. These two planes form an angle at a line in the neutral surface; and, taken together, they form the prime face which marks the uttermost limits of strain. The profile of this prime face is the absolute line of elementary strain. For it is clear that all the strains in the cantilever must finally abut against the prime face, since the prime face is also the interface between the littoral strata which are disturbed and the prime strata which are not disturbed.

The absolute line of elementary strain, the line of reduced resistance to fracture, the future line of principal strain and possibly of ultimate fracture, is therefore a composite line formed by two shorter lines which start from the same point in the neutral surface. One is the line of superior angle against which are abutted all the tensile strains in the upper layers of the cantilever. It will be convenient to call this line the "tensile component" (of the absolute line of elementary strain). The other and lower portion of the composite line is that line of reversed obliquity against which are abutted all the compressive strains in the lower layers of the cantilever. It will be convenient to call this line by a definite name also. Let that name be "the compressive component" (of the absolute line of elementary strain). Then the mean elementary line of strain is that straight line which joins the forward ends of the tensile and compressive components of the absolute line (Fig. 5, Plate VI.).

Now it is evident that if the cantilever were homogeneous, and if the neutral surface were at half-depth, and if the efficiencies of the compressive and tensile stresses to propagate their respective strains were equal, we should, under such conditions, obtain a mean line which would be vertical: for the tensile and compressive components would be equal in length, and equal though opposite in obliquity. The obliquity of one component would thus exactly balance the opposite obliquity of the other, and the mean line would be vertical as stated. This ideal case is illustrated in Fig. 5 (Plate VI.).

It is easy, however, to see that such a balancing of the components is most unlikely, and if it ever really occurs, the conditions must be abnormal, for the resistance of ordinary coal-measure strata to compression is usually greater than their

resistance to tension. Just now we look only at the intrinsic nature of the cantilever, and at once perceive that its neutral surface must lie below the half-depth of the beam. And in the second place, the beam is not homogeneous. The influence of the unstable strata has already been discussed from certain standpoints; and from the present standpoint their influence must be quite obvious. That influence is wholly in the direction of depressing the neutral surface. For whilst, in the absence of lateral freedom, the unstable strata oppose considerable resistance to compression, their resistance to tension is, under any conditions, practically *nil*. And, apart from their own inherent weakness in this direction, they exert a further influence on the cantilever which will be presently noted.

Then, in the third place, we must look not only at the intrinsic nature of this cantilever, but also at the character of its environment. Its inherent properties are such that the cantilever is obviously and measurably stronger to resist compression than tension, but its environment is such that the resistance of the beam to compression straightway becomes immeasurably greater than its resistance to tension can ever be. This enormous disparity of the two opposite resistances is due to the practically infinite lateral resistance of the natural casing in which our cantilever is "fixed." This lateral resistance of the "casing" places no obstacle in the way of the tensile stresses producing their duly effective strains; if anything, it assists them to do so, since lateral pressure naturally tends to longitudinal extension. At any rate, the tensile stresses, in order to produce their effective strains, require longitudinal freedom only, and this is provided for them in the mined area behind. On the other hand, the compressive forces require, as a condition of efficiency, a certain amount of lateral freedom, and of this there is absolutely none, as the lateral resistance is practically infinite. The compressive stresses are so relentlessly hemmed in on all sides by this inexorable resistance that their efficiency to effect strain (in the practical sense of that word) must be next to nothing as compared with the efficiency that might reasonably be expected in the case of any cantilever of similar intrinsic nature, but with ordinary artificial environment. Human skill might conceivably "fix" a cantilever of similar composition, but it could never supply the cantilever with such

a "casing," or endow it with so marvellous an extraneous resistance to its own compressive stresses. Viewed from this broader standpoint of internal nature and external environment combined, there must be little or no exaggeration in the statement that our cantilever is immeasurably stronger to resist compression than it is to resist tension; and, hence, we are bound to infer that its neutral surface is very low down indeed; and probably not many feet above the roof-line itself (Fig. 6, Plate VI.).

Now, if the above views of the intrinsic nature of the rocky cantilever, of the influence of the unstable strata, and of the influence of the unique environment of the cantilever be at all sound, it follows that by far the greater portion of the absolute line of elementary strain is supplied by the tensile component, that by far the greater portion is projected over and towards the solid, and that the mean elementary line must therefore possess a normal obliquity little less in magnitude than that of the tensile component itself. In all probability, the compressive component with its opposite obliquity is confined to the first few feet of, or above, the roof-stratum. The fact that it exists at all explains why careful timbering is requisite for safety, and the exceeding superficiality of its extension explains why such timbering is sufficient to ensure that safety.

Probable Degradation of the Neutral Surface.—In many cases, some of the uppermost strata are specially liable to severe strain, even to partial disintegration, and, on the other hand, they are also specially amenable to any force of reconsolidation. In process of time, it is conceivable and even probable that such strata come to form more and more of a load on the true cantilever, and less and less any effective portion of the beam itself. This may easily occur, although the mining engineer fails to find fractures in the upper absolute roof. It is here assumed that these strata really possess some original definite resistance to tension, and it is not necessary to assume their ultimate definite fracture. It is sufficient to allow that these strata, lying, as they do, along the planes of the greater tensile stresses, may receive severe strain amounting to what is called permanent "set." Either actual fracture or permanent set must have the effect suggested above. Fracture destroys the tensile resistance

entirely; permanent set destroys whatever resilience the bowed strata may have originally possessed. In both cases, the nature of the effects is the same; their degree only is different. In either case, the weight of the upper strata is less appreciably sustained by their own original tenacity and resilient power, and is more fully thrown in the nature of a dead weight on the strata beneath. Stated in brief, the idea is this: We start with a thick unloaded cantilever, and we end with a thinner but loaded beam: thinner, because from the standpoint of their efficiency, the upper layers are gone ; and loaded, because from the standpoint of their dead weight, the upper layers remain only as a true load on the effective beam beneath. This simultaneous thinning and loading of the effective cantilever seems probable for several reasons: the principal one, perhaps, is to be found in the fact that the original beam is a composite beam formed by an aggregation of smaller beams (strata) in superposition. The whole of the composite beam is an effective beam, only so long as its several layers firmly adhere at their conterminous horizontal planes or boundaries. As soon as the uppermost layer (or series of layers) separates from its subjacent layer, or tends to slide thereon, it ceases at once to form any part of the effective cantilever, to which cantilever it must thenceforward sustain the relation of a load only.

Now, if any fixed beam be thinned by removal of its upper layers (Figs. 7 and 8, Plate VI.), it is clear that the neutral surface of the diminished beam will occupy a plane lower in space than that occupied by the neutral surface of the original beam. Continual thinning of the beam must, therefore, result in the continual degradation (through space) of the neutral surface. We may, if we prefer, say that this really represents a series of different beams, each with its own neutral surface; but the writer prefers to consider the case as that of a single beam, the neutral surface of which is liable to shift through the material of the original beam. If equally effective planings were coincidently taken from the underside of the beam, the position of the neutral surface would, of course, be constant. But it is not so; here we have a cantilever practically invulnerable to compressive stress; and, although it finally fails altogether, it fails first at its upper surface, as suggested by the continual projection of the draw in advance of the vertical face. This idea of a shifting of the neutral surface of beams is not, so far as the writer knows,

mooted in mechanical text-books, but it is highly probable that the principle applies with more or less force to all beams, and especially to those which, like that now under review, are built up of distinct layers in superposition. In considering the case of a beam, never likely to receive irrecoverable strain of any of its layers, it is no doubt legitimate to take the position of the neutral surface as constant. But in considering the case of any beam wherein successive layers in turn are liable to receive strains exceeding the elastic limit, it appears to the writer that by the position of the neutral axis we should understand merely its position for the time being.

With regard to the effect of this degradation of the neutral surface through the material of the original cantilever, it must be absolutely clear that each and every shift of the neutral plane will be accompanied by a complete reversal of stress throughout that portion of the beam through which the shift takes place. It has, besides, already been shown that the compressive stresses in the cantilever are practically futile forces, owing to the immeasurably great lateral resistance. But it is obvious that, at every shift of the neutral surface downwards, these previously futile forces must rebound and develop violent reactions in the opposite direction. Probably we can hardly appreciate the magnitude of the phenomena when the tensile and compressive stresses thus "join hands" as it were. It is very likely that the "bowks" or thuds, resembling muffled cannon-reports, which we hear in the upper roof, are due to these sudden reversals of stress; and it is suggestive to remember that these sounding thuds are far more frequently heard in a thick sandstone-roof than in one composed chiefly of shale. In the sandstone, the difference of the tensile and compressive strengths is probably much greater than in the case of the shale, and the depression of the neutral surface is more likely to be of frequent occurrence. It may here be pointed out that the writer deduced the phenomena of intermittent and reversing stresses from the theory set forth in the former paper. It will now appear that they are strongly in evidence from other points of view. Whether we view the situation backward or forward along the line of the direction of working, or across that line; whether we view it from the standpoint of the natural compression of the prime strata *in situ*, or from that of the cantilever-action of the disturbed strata

behind; or from that of the immeasurable resistance of the lateral strata on either side; we are irresistibly led to the recognition of these same reversing stresses.

From general experience, it is found that variation in the amount of stress, and reversal of the direction of stress, are potent factors in the wear-and-tear of machinery and most destructive of the life of material generally. This law has its own analogy and exemplification here. It was pointed out in the former paper that reversing stresses probably accounted for many of the otherwise mysterious accidents from falls which so suddenly and unexpectedly occur under good roofs. It may here be added that these so-called good roofs, sandstones more than others perhaps, are peculiarly liable to those instantaneous reversals of stress which accompany any shift of the neutral surface; and this is so by reason of the peculiarly immense disparity of the respective resistances offered to tension and compression by any cantilever associated with an absolute roof the lower layers of which are chiefly furnished by strong sandstone-strata, or by other strata of a similar nature.

To sum up the points in this argument relating to the cantilever idea: (1) It is agreed that the action of the absolute roof at a longwall-face is that of a cantilever. (2) In any cantilever, the tensile stresses act above, and the compressive stresses act below the neutral surface. (3) The tensile stresses persistently increase as they act along higher and higher planes. (4) On these higher planes, therefore, taken in ascending order, the tensile strains are persistently propagated further and further towards the solid. (5) From which it follows that the tensile component (of the absolute line of elementary strain), against which all the tensile strains are finally abutted, is persistently projected over and towards the solid. (6) But, by reason of its nature and its environment combined, this cantilever of roof-strata is seen to be one the compressive strength of which is many times greater than its tensile strength. (7) Hence, the distance of the neutral surface from the terrestrial surface above is many times greater than its distance from the roof-line below. (8) Consequently, the tensile component must be many times greater than the compressive component of the absolute line of elementary strain. And, therefore (9), the obliquity of the mean line of elementary strain must be very nearly the same as that of the

tensile component itself: the obliquity being such as to project it over and towards the solid. The writer, therefore, submits that the conception of a line of strain projecting over and towards the solid is the distinctly natural and perfectly symmetrical corollary of the cantilever idea, as applied to the absolute roof of longwall workings.

The Incipient Hade-line.—It is certainly allowable to compare like things with like. Therefore, it is proper to study the strains produced by mining subsidences in the light afforded by the known strains produced by subsidences the factors of which are essentially natural. Hence, the writer has sometimes referred (in his former paper) to the elementary line of strain as the incipient hade-line of the embryonic fault created by mining subsidence. It was subsequently objected that such a comparison was inadmissible. The writer would very much like to know why? The geological philosophy of faulting is very simple. There are two classes of faults in nature. One is the normal fault, due to subsidence or upheaval; and the other is the reversed fault, due to plication or folding of the strata (Figs. 9 and 10, Plate VI.). The reversed fault is but the final effect of plication; and mining subsidence has no analogy whatever with that class of fault. The strains and dislocations in the absolute roof are due to subsidence resulting from mining operations. The normal fault is due to subsidence resulting from purely natural causes. It is difficult to perceive why the analogy fails with regard to the ultimate phenomena. By whose practical experience, or by what process of reasoning, has it been established that mining subsidence must follow a law different from that universally obeyed by natural subsidences? Both are primarily due to gravity, both evidence the action of a horizontal motive force; both, so long as they are in the active stage, proceed by waves; and both develop their lines of strain along the path of the oblique force that produces them. Then, after the active subsidence has come to an end in both cases, why should one develop the inevitable hade-plane of the normal fault, whilst the other develops something quite different? Until these questions are answered, the writer is bound to believe in the immutability of natural law; and bound, therefore, to believe that the ultimate phenomena developed by mining sub-

sidence are essentially of the same class as those which we daily prove to have been developed by natural subsidence. It is perfectly competent to compare like things with like, and perfectly legitimate to study the obscure phenomena of mining subsidence, during its transitional stage, in the light afforded by the fully developed features displayed by natural subsidence in its ultimate stage.

An imaginary case may suggest much, though it proves nothing. Here, at a depth, say, of 1,000 feet is the goaf of a coal-seam, 6 feet thick, which has been worked out over a square area, 1 mile on the side. A seam, 2 feet thick, lying 100 feet above, has been abandoned. Two centuries later, shafts are put down to win this thin upper seam. The question is whether this seam will be found faulted at some plane proceeding from the goaf-boundary below. We may be very sure that it will. The throw of this fault will be less than the subsidence of the nether roof below, but it will be greater than the subsidence of the surface vertically above. Then, will the fault be of the normal, or of the reversed type? We can safely predict that it will not be a reversed fault; for all the conditions associated with the reversed fault found in nature are absolutely absent. It can, with almost equal confidence, be predicted that the fault will be normal; for, as far as our information goes, all the conditions usually associated with the normal fault, found in nature, are present. In predicting the normalization of the fault, we merely predict that the subsidence in this particular case will follow the same law as that followed by subsidences in the general case. But if the fault be normal, its hade-line is normal, and it is projected over and towards the solid; and it evidently follows the line of reduced resistance furnished by the elementary line of strain in the roof of the seam below; which line, in the long ago, must have been projected in the same direction. As already stated, this imaginary case proves nothing either one way or the other; but it is suggestive, and enables one to form a pretty good idea as to whether or not this theory of an ascending line of strain is consistent with the accepted canons of modern physical science. It rests with those who do not accept this very natural theory to explain away, if they can, the salient fact of this rising line forming the profile of every normal hade-plane found in nature.

Synopsis and Conclusion.—The present paper merely gives the argument for the general case, apart from modifications due to local causes. But, since the entire action of the absolute roof can never be displayed in our actual physical view, the case is obviously one of that numerous class where direct absolute proof is impossible. The available proof is therefore presumptive and cumulative. Yet every argument herein adduced is a natural and not a far-fetched argument. For purposes of ready reference, these arguments are summarized below.

(1) Subsidence at the surface and subsidence at the nether roof-line prove that the absolute roof is disturbed throughout its entire depth.

(2) But the efficiency of the mining timber proves that the greater bulk of the absolute roof is sustained by horizontal thrust.

(3) The radial projection of the surface-draw across the annular littoral zone suggests that the whole volume of subsided and subsiding strata approximates in shape to the frustum of an inverted cone. If this be so, the entire slant surface of the inverted conic frustum is coincident with a great plane of strain which projects over and towards the solid on all sides of the excavation.

(4) The known properties of the less stable strata contained in the roof imply that, as subsidence takes place, they will tend to slide on their appropriate angles of repose; and thus tend to project the great planes of strain over and towards the solid.

(5) By common agreement, the more stable strata act as a cantilever hanging over the face of work. The neutral surface of this cantilever is very low down, and since the propagation of the several strains is proportional to the magnitude of the several stresses, it is inferred that the mean line of strain at the face of the prime strata is, by the action of this cantilever, projected over and towards the solid.

(6) From the history of the earth, and from orthodox geological science generally, we know that strata *in situ*, both stable and unstable, possess a large amount of potential horizontal force, as well as a large amount of potential vertical force.

(7) From the fact that the mining operations create a region of lessened resistance, we infer that both these forces, originally potential, become eventually kinetic; the liberation of the

vertical force setting free the potential horizontal force inherent in the strata.

(8) Both of these kinetic forces act towards the region of least resistance, and the region of least resistance is furnished by the excavation and by the disturbed mined strata. The vertical force of gravity acts downward towards the mined area; and the horizontal motive force, created by the difference of the horizontal resistances, acts backwards from the prime strata and towards the mined strata.

(9) The vertical force, acting downward, is one component of the total roof-action; and the horizontal motive force, acting oppositely to the direction of working, is the other component. Hence, the total roof-action proceeds in the oblique direction denoted by the geometrical resultant in the parallelogram of those forces. This direction is evidently downward and backward (Fig. 11, Plate VI.).

(10) From the physical law that action and reaction are equal and opposite, it is deduced that the line of total reaction upon the roof itself is equal and opposite to the line of total action exerted by the roof. Thus: the line of vertical action, the line of horizontal action, and the line of total reaction, taken in order, form the perpendicular, the base, and the hypothenuse of a triangle of forces in equilibrium (Fig. 12, Plate VI.). The line of reaction is therefore upward and forward, and the great planes of strain in the absolute roof are projected over and towards the solid.

(11) When we examine the case of natural subsidences of the earth's crust, we find again that the great (hade-) planes of strain, in the normal case, are always projected over and towards the solid (or unsubsided) strata.

Thus, whether we consider the projection of draw as set forth in the third argument, or whether we consider the action of the less stable strata as set forth in the fourth, or whether we consider the cantilever-action of the more stable strata as set forth in the fifth, or whether we consider the natural forces inherent in the entire roof-body as set forth in the sixth to the tenth, we are irresistibly led to the following intensely natural conclusion that:

(12) During its comparatively obscure transitional stages, mining subsidence constantly obeys (in the present) the same general rule as that known to have been obeyed (in the past) by

natural subsidences, the ultimate stages of which are now manifest all over the globe. This rule is the law of the normal fault as set forth in the eleventh conclusion, and mining subsidences with natural subsidences alike project their great planes of strain over and towards the solid.

Hence, in this paper, the obliquity of the ascending line of strain has been called the normal obliquity. It is the obliquity of a normal hade-plane. In natural faults, we may observe the ultimate strain: the plane of fully-developed fracture. In the case of a mine, however, the phenomena are not yet fully developed, and the "hade-plane" is merely a plane of strain without being necessarily a plane of actual fracture. Hence the term "incipient hade" has been employed in this and the former paper. It is incipient only, because, in the practical case of a mine, the wave of subsidence is still in motion. Scarcely is one hade-plane incipient than the strata beyond it also begin to subside, and a further embryonic hade-plane is created at the newer face of prime strata. But whether these hade-planes be developed or be merely in embryo, they finally form the typical "great planes of strain" in the absolute roof of the mine. For each successive incipient hade-plane is evidently an initial plane of reduced resistance, and must, in the natural order of things, eventually develop into a principal plane of strain as the wave of subsidence continually flows onward in the direction of working.

The writer respectfully submits that this theory of the normal obliquity of the great planes of strain, induced by the subsidence of the absolute roof, is a perfectly natural and an entirely reasonable theory. As to the practical results which follow therefrom, and as to the otherwise obscure mining phenomena which the theory accounts for and explains, some of these were indicated in the former paper, and others may be indicated in the future. Members are cordially invited to re-examine the previous paper after they have accorded to the present one their kind and valued consideration. Both papers are chapters from the same book of nature; but, owing to the reasons given in the introduction to the present paper, the mental or natural sequence of the two papers is the reverse of their chronological order; and this paper, the last one written, should therefore be read first.

LIST OF ILLUSTRATIONS (PLATE VI.).

The aim of the drawings is to illustrate the principles rather than the details of the writer's paper. In order to avoid having recourse to unduly large drawings, the coal-seams are drawn much too thick. They are drawn thick enough to be conspicuous, but, except in Figs. 9 and 10, they are too thick to harmonize with the rest of the drawing. In effect, it may be considered that the absolute roof is drawn to a smaller vertical scale than the coal-seam below.

FIG. 1.—*Profiles of the Surface.*—ABCD is a profile of the original surface, and EFGC a profile of the subsided surface: the subsidence being exaggerated for clearness. The arrow shows the direction of working. EF is the surface of the dead strata; FG is the surface of the motive zone; GC is that of the littoral zone, and CD lies on the surface of the prime strata. The vertical line BH lies in the vertical plane of the face-line; and BC is the draw beyond the vertical face.

FIG. 2.—*Frustum of Subsided Strata.*—AB and CD lie on the surface of the prime strata. The broken line BC is the original level of the surface now subsided to BSC. BEFC is the inverted conic frustum of subsided strata, and GH is the coal-seam, which is being worked in all directions on a circular line of face.

FIG. 3.—*Diagram of Obliquities.*—VL is the vertical line; and AD shows the horizontal direction of working. AB is an ascending line of normal obliquity and of superior angle, θ; whilst AC is a descending line of reversed obliquity, and of inferior angle, ϕ.

FIG. 4.—*Arching of the Roof.*—The plane at A is the plane of maximum stress and maximum propagation of strain in the original bridge-structure, hence A is in the widest part of the arch subsequently formed. At E and F, the stresses are less; the propagations of strain are less, and the arch is less wide at these planes as a consequence.

FIG. 5.—*Stress-diagram of an Ideal Homogeneous Cantilever.*—The neutral surface is at NS, at half the depth of the beam. The stresses in the upper section, *a*, are tensional, and attain a maximum at the surface-line, A. The strains propagated by the tensional stresses finally abut on the tensile component, AB. The stresses in the lower section, *b*, below the neutral surface, NS, are compressive; their maximum is found on the roof-line, C; and they finally abut against the compressive component, BC. ABC is the absolute line, and AC is the mean line of elementary strain: in this case, vertical.

FIG. 6.—*Stress-diagram of a Cantilever, with a Low-down Neutral Surface.*—The neutral surface lies in the plane NS. The propagations of the strains are again shown by the double arrows in (*a*) and (*b*). AS is the tensile component; SC the compressive component; and the broken line, CA, represents the mean elementary line of strain projecting over and towards the solid.

FIGS. 7 AND 8.—*Degradation of the Neutral Surface.*—Fig. 7 shows a thick cantilever (of homogeneous composition) the neutral surface of which is in the plane NS. In Fig. 8, the cantilever has been shorn of its upper layers to half the depth of the beam; and the cuttings have been left as a load, L, on the beam. The neutral surface of the diminished beam is now on the plane *ns*; and it has been shifted through a distance equal to S*n*. In the original beam (Fig. 7) all the layers between N and *s* were in compression; in Fig. 8, the same layers are in tension. Hence, all the layers between N and *s* have undergone a complete reversal of stress, as the result of thinning the original beam (Fig. 7).

FIGS. 9 AND 10.—*Faults.*—The figures illustrate typical cases; but it is not pretended that there is no variety of cases in each class. The figures are, however, intended to portray the essential conditions which differentiate the one class of

fault from the other. AB represents the normal hade-line of a normal fault (Fig. 9); and AC the abnormal hade-line of a reversed fault (Fig. 10).

FIG. 11.—*Parallelogram of Forces.*—AB is the force of gravity; BC is the horizontal motive force; and AC the resultant obtained by the compounding of these two forces. The arrow-heads on the lines of the triangle show the direction of motion of the forces, and the arrow, *a*, shows the direction of working. In nature, the superior angle ACB of the hade-line is sometimes less than that shown in the figure, and sometimes greater. In mining, it is sufficient if the angle of the elementary line be superior, and less important, whether it be large or small.

FIG. 12.—*Triangle of Forces in Equilibrium.*—AB is the gravitational force of the roof-action; BC is the horizontal force of the roof-action; and CA, the total force of the reaction upon the roof itself, is equal and opposite in direction to AC of Fig. 11. The arrow-heads on the lines of the triangle again show the direction of the linear forces, and the arrow, *a*, the relative direction of working.

The PRESIDENT (Mr. T. W. Benson) moved a vote of thanks to Mr. H. W. G. Halbaum for his interesting and valuable paper.

Mr. T. E. FORSTER seconded the resolution, which was cordially approved.

THE MINING INSTITUTE OF SCOTLAND.

GENERAL MEETING,
HELD IN THE HALL OF THE INSTITUTE, HAMILTON, DECEMBER 14TH, 1905.

DR. ROBERT THOMAS MOORE, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen were elected:—

MEMBERS—

Mr. JAMES McCOMB, Glenview, Dykehead, Shotts.
Mr. GEORGE McDONALD, Ellenborough Colliery, Maryport.

ASSOCIATE MEMBER—

Mr. JAMES BARROWMAN, jun., Staneacre, Hamilton.

DISCUSSION OF MR. ROBERT CRAWFORD'S PAPER ON A "HYDRAULIC PUMPING-INSTALLATION AT LOANHEAD COLLIERY, NEAR EDINBURGH."*

Mr. ROBERT CRAWFORD, replying to the previous discussion, wrote, with reference to Mr. James Hamilton's remarks as to the difficulties encountered on starting, that it was natural to expect, when pioneering with a new gear, that difficulties, unseen by the patentees, would require to be overcome in actual practice.

On the starting of the hydraulic pump at Loanhead, a few difficulties presented themselves: thus, the packing-boxes of the power- and pump-barrels were found to be too shallow to allow of sufficient rounds of packing being inserted so as to withstand the high pressures, such as existed in these cylinders, with the result that frequent packing became a source of much trouble and expense. To overcome this difficulty, the packing-boxes were increased in depth from 7 inches to 13½ inches: this alteration giving satisfactory results.

* *Trans. Inst. M. E.*, 1905, vol. xxx., page 64.

Some difficulty was experienced in finding a suitable kind of packing, and various kinds were tried, namely, asbestos, flax, compensating, and latterly plumbago, which was giving satisfaction.

The rams were made of cast-iron, but they were found to have a detrimental effect upon the packing when they became corroded through the action of the water upon them; and they were now covered with a liner of gun-metal.

Guttapercha constituted the beats of the suction- and delivery-valves, but it was found to be too soft to withstand the high pressures, and required renewal about every week. Antifriction white-metal had been substituted for the gutta-percha; and these valves now worked for six months without changing.

The mushroom-shaped power-valve was primarily made of steel, but it was found that the action of the water upon it caused corrosion, thereby destroying the beat of the valve. To overcome this defect, a gun-metal valve was substituted, and the length was increased from 4½ inches to 7 inches. This form of motor-valve also admitted of the application of the hydraulic system to haulage as well as to pumping purposes. One particular feature in connection with the motor-valve was that it was perfectly balanced. The valve-spindle and the face of the exhaust-valve were of precisely the same diameter, and they opposed each other under all conditions of pressure. It was therefore a matter of indifference whether the two exhaust-valves were both off their faces together: that is, both ends of the power-ram would be in communication with the return-water pressure; or the exhaust-valves might be closed, and both ends of the power-ram would be subject to the driving pressure; or, finally, the power-valves could be forced into any position, one open to the power, and the other open to the exhaust, with the same effect.

The maximum head against which these pumps could work was governed by the tensile and crushing strain of the material of which the valve was made. The pumps could be made to work with a maximum pressure of 2 to 3 tons per square inch.

The PRESIDENT (Dr. R. T. Moore) said that the principle of pumping water by hydraulic power had been applied at several

collieries, both in this country and abroad. It was a favourite system in Germany, where large quantities of water had been pumped to great heads; and the same system had been applied at docks. The essential point, in getting a high useful effect out of any hydraulic arrangement, was that the load should be uniform so that the hydraulic engine should be doing the amount of work for which it had been designed. With a steam-engine doing a light load, the steam expanded in the cylinders, and a less quantity was used than when the engine was working against a heavy load. In the case of a hydraulic engine, the water did not expand, and the same amount of power was taken to drive the engine, whether it was working with a full or with a half load. With a variable load, therefore, the efficiency was much smaller than with a steady load. The plant described in Mr. Crawford's paper comprized an engine supplying power to a pump, and that was one of the cases especially suitable for the use of hydraulic power; and he had no doubt that a high efficiency was obtained, better, probably, than would have been got by the use of electricity. He noticed that Mr. Crawford had steam-accumulators for taking up shocks in the power-water: accumulators of some kind were absolutely necessary, as it was difficult to avoid shocks in hydraulic work. He was not sure, however, that a steam-accumulator was better than an air-vessel, which was simpler and served the same purpose. In conclusion, he moved that a hearty vote of thanks be given to Mr. Crawford foı his paper.

Mr. T. H. Mottram read the following "Description of the Sinking of Shafts through Sand at Ardeer, Ayrshire, by the Pneumatic Process, with Notes on the Subject of Caisson-ventilation and Sickness":—

DESCRIPTION OF THE SINKING OF SHAFTS THROUGH SAND AT ARDEER, AYRSHIRE, BY THE PNEUMATIC PROCESS, WITH NOTES ON THE SUBJECT OF CAISSON-VENTILATION AND SICKNESS.

By THOMAS H. MOTTRAM, H.M. Inspector of Mines.

Introduction.—Two pits are being sunk on the sea-shore for the Glengarnock Iron and Steel Company, Limited (of which Mr. Robert Main is the general manager and director), for the purpose of working the coal lying underneath that portion of the Firth of Clyde, known as Irvine bay, extending from Saltcoats on the north to Irvine on the south.

The coast-line, for some miles in that locality, is marked by numerous ridges of sand-hills, apparently formed by blown sand from the sea-beach. The coal-seams, lying underneath, belong to the Upper Coal-measures, the bottom seam in the series being but a short distance above the Upper Limestone beds; the Millstone Grit is evidently very thin, or altogether absent. This may be seen by a glance at the map of the Geological Survey,* which shews the Carboniferous Limestone series coming to the surface underneath the Upper Coal-measures on the north side of the Saltcoats and Kilwinning coal-fields.

At present, mining operations in the neighbourhood of Saltcoats and Ardeer are confined to the Upper Coal-measures, and the principal seams of that series are being worked northwest of Ardeer by the Glengarnock Iron and Steel Company, Limited, underneath the sea from the adjoining estate of Auchenharvie. Table I. comprizes a general section of the different coal-seams in the locality.

The Ardeer and Auchenharvie estates are divided by a well-known doleritic intrusion, called the Capon-Craig Gaw, which runs from a point about ½ mile northwest of the town of Stevenston in a south-easterly direction underneath the sea. This Gaw

* *Geological Survey of Scotland*, Sheet 22, Kilmarnock.

forms a natural barrier between the two estates and by an ancient stipulation (carried forward from the old to the new mineral leases) the Gaw cannot be cut on either side, so that the working of the minerals in the one estate must be carried out independently of that in the other.

TABLE I.—GENERAL SECTION OF THE COAL-SEAMS AT ARDEER, AYRSHIRE.

No.	Coal-seams.	Ft.	Ins.	Thickness of Seams. Ft.	Ins.	Depth from Surface. Feet.
1	*Bowbrig Coal-seam*—					
	COAL ...	0	10			
	Stone	1	0			
	COAL ..	2	0			
		——		3	10	474
2	*Crawford Coal-seam*—					
	COAL ..	1	8			
	Stone	1	6			
	COAL ...	0	10			
		——		4	0	552
3	*Five-Quarter Coal-seam*—					
	COAL			3	6	636
4	*Parrot Coal-seam*—					
	COAL ...	4	4			
	COAL, parrot	0	8			
		——		5	0	696
5	*Turf Coal-seam*—					
	COAL			2	8	714
6	*Wee Coal-seam*—					
	COAL			2	4	726
7	*Ladyha' Coal-Seam*—					
	COAL			2	5	882
8	*Ell Coal-seam*—					
	COAL			2	10	906
9	*Main Coal-seam*—					
	COAL ...	1	8			
	Stone	0	10			
	COAL ...	1	8			
		——		4	2	996
10	*Raise Coal-seam*—					
	COAL			3	0	1,056

Some of the coal-seams had already been worked in the Ardeer estate down to a "want" on the rise side of the present sinking; and as the new pits are required to work the coal between this "want" and the Capon-Craig Gaw, it was deemed advisable to sink them as far as possible to the dip of the old workings. This explains why the shafts are being sunk so near to the sea. In the meantime, the slag-tip from the Ardeer furnaces has been diverted along the coast-line, and, in course of time, will form a protection for the new colliery. It is also intended to form a shipping-place, by the construction of two breakwaters, opposite the property of the Glengarnock Iron and Steel Company, Limited; and, with this in view, application has been made to the Board of Trade for permission to enclose a water-space of 2,300 feet by 1,000 feet. The height of the breakwaters will be about 8 feet above the level of high-water mark of ordinary spring tides.

As a preliminary to the sinking of the shafts, Mr. Main put down surface bore-holes to the rock-head; and the one, with the section recorded in Table II., was considered by him to contain the strata most suitable, and now forms the site of the No. 1 shaft. A section of the strata bored through in No. 5 bore-hole,

to a depth of 200 feet, is printed in Appendix I. The position of this bore-hole forms the site of No. 2 shaft.

TABLE II.—SECTION OF STRATA IN NO. 3 BORE-HOLE.

No.	Description of Strata	Thickness of Strata Ft. Ins.	Depth from Surface. Ft. Ins.	No.	Description of Strata.	Thickness of Strata. Ft. Ins.	Depth from Surface. Ft. Ins.
1	Dry sand	17 0	17 0	5	Muddy clay, with stones	6 0	69 0
2	Wet sand	36 0	53 0	6	Stiff clay, with boulders	14 0	83 0
3	Wet sand, with shells	8 0	61 0	7	Green sandstone, into	...	...
4	Gravel	2 0	63 0				

Sinking through wet sand is well known to be at all times difficult and costly, and not always successful. After mature consideration it was decided to sink the Ardeer shafts down to the rock by means of compressed air, and the assistance of the firm of Sir William Arrol, Limited, was obtained for this purpose.

When a shaft is sunk by the pneumatic process, the lining is generally called a caisson, which, in form, may be likened (as far as the outer shell is concerned) to an inverted tumbler, charged with air above the normal pressure, the edge of the glass representing the cutting-edge of the caisson; and the top, the base upon which the winding-apparatus, locks, etc., are placed. The weight of the caisson, including the superstructure, forces the cutting-edge into the strata; and, as the strata inside are removed, the caisson sinks and forms the wall of the new shaft. As a general rule, little or no additional weight other than that of the winding-apparatus and locks is required at the early stages of the sinking; but, as the skin-friction caused by the strata pressing against the outer wall of the caisson increases, additional weight is required to be added to the superstructure. This weight is sometimes very considerable, and may run into hundreds of tons.

Where the strata consist of soft material, and the digging inside the caisson is evenly done, the keeping of the structure in a vertical position is not, as a rule, a very difficult matter; but, in the event of the caisson deviating from the plumb-line, as it may do through subterranean influences or through the occurrence of boulders in the strata, the additional weight, or "kentledge" as it is sometimes called, must be so distributed as to check and remedy the defect during the continuance of the sinking.

The compressed air inside the caisson retards the lowering of the structure; and, as a rule, the air-pressure is lowered in the absence of the sinkers, so as to allow the caisson to sink.

Fig. 1 is a general view of the Ardeer sinking. The background is the sea, and in the front, on the extreme left, No. 1 caisson may be noticed, the shell projecting several feet above the ground. No. 2 caisson may be seen on the right, with the

FIG. 1.—VIEW OF NOS. 1 AND 2 SHAFTS, ARDEER.

material-lock and winding-apparatus on the top. Below these, a large quantity of pig-iron is stacked upon the top of the caisson to force it downward, and on the left, immediately above the pig-iron, can be seen the wheels, one nearly above the other, belonging to the valves of the material-lock. As these valves played an important part in the winding arrangements, their manipulation will be referred to again later on.

In the course of sinking, the winding-apparatus, lock, etc., required to be removed from one shaft to the other, and cranes were erected between the two caissons to facilitate their removal.

Fig. 2 is a view of the top of No. 2 caisson, when sinking was in actual progress. The ends of the girders, resting on the

top of the caisson and carrying the pig-iron, are visible, together with the winding machinery and the entrance to the man-lock; the rectangular-shaped opening to the latter being seen to the left of the ladder-top, but the door which opens inwards is not seen. The whole structure rested on the top of the shaft.

In the foreground are a few of the segments used in the construction of the caisson.

Fig. 3 (Plate VII.) is a plan of the surface-arrangements.

FIG. 2.—VIEW OF NO. 2 SHAFT, ARDEER.

Compressed-air Plant and Winding Machinery.—The air-compressor had an air-cylinder, 12 inches in diameter and 3 feet stroke; a steam-cylinder, 12 inches in diameter; and a flywheel, 6½ feet in diameter. The boiler, of Robey type, 13 feet long and 4 feet in diameter, was worked at a pressure of 100 pounds per square inch.

The air was conveyed to a receiver (8 feet long and 2½ feet in diameter) by a pipe (2 inches in diameter), a similar pipe being led from the air-receiver to the caisson. This pipe was attached to a flexible wire hose-pipe fitted to a check-valve on the side of the caisson, so as to avoid a sudden fall of pressure inside the caisson, in the event of a stoppage of the air-compressor or an interruption in the air-supply.

The winding of the material out of the caisson was done by a steam-winch, fitted on the material-lock. This engine had two cylinders, each 6 inches in diameter; the winding-drum was 3 feet in diameter; the steel winding-rope was ½ inch in diameter; and the kettle was 3 feet deep and 2 feet in diameter. The winding-drum and rope were enclosed in a chamber attached to the material-lock, the drum being driven by worm-gearing off the driving-shaft. The winding from the lock to the tip of the shute was done by a separate rope and drum, the pulley being fixed on a frame constructed of angle-iron, a few feet above the lock.

Air-locks.—There were two air-locks (Fig. 4, Plate VII.), one for the ingress and egress of the workers, and the other for the passage of the débris from the caisson to the surface. The man-lock (Fig. 4) was at the side of the tube on the top of the diaphragm, and, being 6 feet high and 3 feet wide, was capable of comfortably holding four or five men. The inlet- and outlet-doors, 2 feet 6 inches high and 1 foot 8 inches wide, were lined with rubber at the joints. At the top of the locks, there were two cocks, $\frac{5}{16}$ and ¾ inch in diameter, for the admission of compressed air from the caisson.

The material-lock, for the débris, was placed at the top of the tube and had similar dimensions, the doors or valves, however, being placed horizontally and fitted with an interlocking arrangement of simple construction. It consisted of a vertical bar and lever, the valve-rods being slotted, so that when the bar was lifted into the slot of the top-rod, the lower door only could be opened; and, *vice versa*, when the vertical bar was lowered, only the top-door could be drawn. This arrangement made it impossible that both doors should be open at one time.

To gain admission to the man-lock or chamber, it was necessary to enter the outer door, which was then closed, the india-rubber-ring on the door making a tight joint. One of the air-cocks was then opened so as to admit gradually the compressed air. The time taken in doing this was somewhat regulated by the pressure of the air admitted, and is referred to elsewhere. The writer, during transit through the air-lock, usually took 6 to 9 minutes in admitting the air. As soon as the pressure on both sides of the inner door was equal, the door leading to the

tube was easily opened. The top of the caisson or scaffold resting thereon was conveniently reached by descending an iron-ladder placed inside the tube. The bottom of the shaft was gained by an iron-rope ladder, the winding-apparatus being used only for the removal of the débris. The return from the shaft-bottom was the exact reverse of this, the pressure of the outer chamber (after the closing of the inner door) being exhausted by opening a small air-cock communicating with the atmosphere. The air-cocks exhausting the high-pressure air were made small, so as to prevent anyone making the change too quickly, for, if this were done, the person exposed to it might run risk of injury.

The mode of working the material-lock was as follows:—The top door of the material-lock being drawn open, the kettle was lowered into the lock, and the shackle of the inside winding-rope attached to it. The upper door was then closed, and a slight movement of the engine tightened the rope lifting the bucket just clear of the lower door. An air-cock or valve, communicating with the compressed air in the caisson, was then opened, and pressure admitted to the lock containing the bucket. As no workmen passed through the lock, it was not necessary, as in the case of the man-lock, to admit the compressed air gradually, and, consequently, the inlet- and outlet-cocks were large, and acted expeditiously to avoid loss of time. When the pressure inside the lock equalled that in the caisson, a turn of the interlocking wheel set the lower door free. This door was then drawn back, and the kettle lowered to the bottom of the shaft. An indicator on the winding-engine shewed the position of the kettle at all points of its course. As in the case of the man-lock, the outward passage of the kettle containing débris was the exact reverse of the inward process. The engineman was signalled to, by means of a wire attached to a compressed-air whistle.

Shafts or Caissons.—The shafts are sunk 48 feet apart. The caisson consists of a steel-shell, ½ inch thick, 17 feet 7 inches in external diameter. The inside is lined with brickwork, 18 inches thick, and concrete, 3 inches thick, is placed between the brickwork and the steel-shell. The internal diameter of the finished shafts is 14 feet.

Steel-work.—The shell, *h* (Fig. 5, Plate VII.), is built of steel-plates, ½ inch thick, 12 feet 4½ inches long, and 6 feet high. These plates were fitted up in the engineers' shop beforehand, so as to involve as little adjustment as possible at the sinking. The butt-joints of the plates were made with shell-covers or butt-straps, the vertical straps, *d* and *f*, being drawn out at each end to fit below the longitudinal straps, *e* and *g*. In the first seven courses (A, and B_1 to B_6), on the top of the cutting-edge, the straps, *d*, were ½ inch thick and 5½ inches wide, and above that, *f* (C_1 to C_6 and D), ½ inch thick and 9 inches wide. In the case of the smaller straps, there were two rows, and in the larger ones four rows of rivets. The pitch of the rivet-holes was $3\frac{5}{16}$ inches and 2¼ inches respectively. The plates were countersunk, snap-headed rivets being used to form as smooth a surface as possible on the outside of the shell. In each of the longitudinal straps, *e* and *g*, 168 rivets were used; and in the narrow and wide vertical straps *d* and *f*, the numbers were 60 and 118 respectively. All the rivetting was done by hand.

Cutting-edge.—The cutting-edge, *a*, 17 feet 9 inches in external diameter, was formed by an additional steel-ring, 1 inch thick and 10 inches high, rivetted flush with the bottom of the shell. The covers of the joints of the cutting-ring were 7 inches wide and 1 inch thick. About 10 inches above the cutting-edge a ring of angle-iron, 6 inches wide, 3 inches deep and ½ inch thick, formed a bracket, *b*, or foundation for the bevelled brickwork; and 2 feet 7½ inches higher, there was a shelf-plate, *c*, 1 foot 3½ inches wide and ½ inch thick, supported by sixteen brackets made up of gusset-plates, ⅜ inch thick, and angle-irons, 3 inches wide, 3 inches deep and ½ inch thick, carried the concrete and brickwork lining. The joints of the angle-iron, *b*, had top and bottom covers, 5 inches wide and ½ inch thick. The shelf-plate, *c*, was attached to the shell by an angle-iron, 3½ inches wide, 3½ inches deep and ½ inch thick, with covers 3 inches wide and ½ inch thick.

The top of the shell will ultimately be finished off with an external ring, *i*, of angle-iron, 3½ inches wide, 3 inches deep and ½ inch thick. While sinking, the shell-top was covered with a diaphragm-plate, ⅝ inch thick, supported by four girders, 2 feet 6 inches deep, 2 inches wide, and ⅝ inch thick flange-plates

with $\frac{5}{8}$ inch web. This diaphragm-plate, in addition to carrying the tube (5 feet long, 3 feet 8 inches in diameter and $\frac{3}{8}$ inch thick) leading from the caisson to the air-locks, also supported the locks and winding-apparatus.

Brickwork and Concrete-lining.—The brickwork consisted of two rows of firebricks, 3 inches thick and 9 inches long, bonded horizontally in two parts of Portland cement mixed with one of sand. The concrete-filling, between the brickwork and the shell, was 3 inches thick, and made of four parts of broken brick to one of cement.

Sinking Operations.—As will be seen from the journal (Appendix II.), actual sinking was started in No. 1 shaft on December 1st, 1904, and by December 17th the caisson had reached water-level, $17\frac{3}{4}$ feet below the surface. No. 2 shaft (Appendix III.) was started on December 22nd, 1904, and sinking in the open continued until January 5th, 1905, when the caisson in this shaft also reached water-level. After reaching water-level, the shells were cased with brickwork and concrete.

The methods employed in sinking both shafts were identical, but they were sunk, by degrees, alternately. No. 1 shaft being the first bricked, was fitted with the necessary machinery, deck, locks, etc. This operation was finished on February 18th, 1905; sinking by the aid of compressed air was then started and continued until February 25th, 1905, on which date the caisson had reached a depth of 36 feet. The air-pressure inside the caisson down to this level was only 7 pounds per square inch above the atmosphere, and during each night the pressure was taken off for $\frac{1}{2}$ hour to enable the caisson to sink, as the excavation deepened.

At this point, it was deemed advisable to resume the bricking of No. 1 shaft, and meantime the locks, etc., were shifted to No. 2 shaft, an operation which occupied from February 25th to March 14th, 1905; and, by a similar method, this shaft was deepened to $36\frac{1}{2}$ feet; this depth being attained on March 22nd, 1905.

Meanwhile, the bricking of No. 1 shaft having been finished, the air-locks, etc., were again put in position at the pit-head and from April 5th to April 17th, this shaft was sunk from $36\frac{1}{2}$ feet to 54 feet, the air-pressure being 14 pounds per square inch.

From April 17th to April 24th, the shifting of the locks again took place, and, between April 24th and May 6th, No. 2 shaft was sunk down to the same depth as No. 1 shaft, namely, 54 feet. On May 21st, sinking in No. 1 shaft was again resumed, and by July 12th the depth was 78 feet 9 inches, and the air-pressure 19 pounds per square inch.

From August 1st to 30th, No. 2 shaft was sunk from 54 feet to 79 feet 9 inches, and, there being little water, the centre of the shaft was sumped on to the rock a further distance of 10 feet 3 inches by September 4th. At this date operations were again diverted to No. 1 shaft, and, owing to the accumulation of water, the winding of water occupied from September 25th to October 3rd, on which date sinking was resumed. By October 12th, the caisson was down to the rock at a depth of 85 feet, and by October 16th, 1905, the brickwork between the rock-head and the shelf carrying the brickwork above, was finished. Three weeks later No. 2 shaft was also down to the rock-head at a depth of 90 feet. Figs. 6 and 7 (Plate VII.) show how both caissons were secured at the rock-head so as to ensure water-tight joints. Both shafts down to the rock-head are practically dry.

Appendices II. and III. contain a detailed daily record of the sinking operations kept by Mr. A. L. Forsyth, superintendent. It is interesting to note that while No. 1 shaft deviates 8 inches from the plumb-line, No. 2 shaft is quite plumb.

Water.—The pneumatic process, as has been stated, came into operation as soon as the water-level was reached. The increased pressure inside the caisson, together with the assistance of a pipe, by which some of the water was blown from the pit-bottom to the surface, successfully dealt with the water until the clay was reached. At this point, a tight joint was formed between the clay and the caisson and the question of continuing the sinking of No. 1 shaft in the open was considered; but, after a while, the water in the shaft-bottom, which had been as low as a gallon a minute increased to 20 or 30 gallons.

Mr. Main then decided, in order to avoid risk to the caisson, to resume the use of compressed air. Greater difficulty was experienced with the water in No. 1 than in No. 2 shaft. In the former, when passing through the boulder-clay, a little blasting had been done. It is thought that this may have damaged the

water-tight joint, referred to above; and, later on, when the water-pipe was being used with a pressure of 36 pounds per square inch for the purpose of drying the pit-bottom in the absence of sinkers a "blow" occurred, and water was forced to the surface outside of the shaft at the weakest point. The use of the water-pipe was abandoned after this: any excess of water not forced back by the air, which naturally gravitated to the pit-bottom, being drawn out by the kettle; and between September 25th and October 2nd, 1905, about a week was spent doing this. In No. 2 shaft, little water was met with after getting into the boulder-clay, and the shaft was sunk dry down to the rock-head.

Air-pressure.—As previously stated, the pressure inside the caisson varied from time to time. It naturally increased, in water-bearing strata, as the depth of the caisson increased, the pressure being equivalent to the static head of water *plus* the friction of the air flowing to the point at which the pressure kept it back. When started at water-level, the pressure inside the caisson was about 7 pounds per square inch above that of the atmosphere. It increased to 22 pounds, until the shafts passed through water-bearing strata. Below that depth, the necessary pressure was found to be less, and after the caisson passed into clay there was less loss of air by percolation, and consequently the air-pressure was the more easily maintained. Occasionally, higher pressures were employed, for instance, when the water-pipe was used for blowing out the water; but this was done when the pressure was excessive, and when the sinkers were out of the shaft.

Kentledge.—Until No. 1 shaft reached a depth of 54 feet, the only weight on the cutting-edge was that of the caisson itself *plus* the weight of the deck, air-locks, and the brick-lining. On October 5th, 1905, when the shaft was 79½ feet deep, the weight had materially increased and was as follows:—Pig-iron, 480 tons; steel-shell, 52 tons; brickwork and concrete, 234 tons; and deck and air-locks, 18 tons.

These weights will give an idea of the work involved, as the shafts deepened, in transferring the air-locks, etc., from one shaft to another. In order to avoid the removal of the pig-iron, etc.,

as long as possible, an open trench was dug round the shaft, at the surface, to a depth of 8 or 9 feet; and, by this means, the base of the whole structure on the surface could be lowered below surface-level.

Ventilation.—Owing to the plan adopted in the sinking of these pits the methods usually practised in ventilating sinking pits were unsuitable. The pipe admitting the compressed air at the top of the caisson was 3 inches in diameter; and, after the air was compressed to the pressure required to dry the pit-bottom, it was evident, from the fact that the air-compressor perforce continued to inject air to keep up a constant pressure, that there must have been percolations of air from the caisson.

The quantity of air admitted to the caisson varied, according to the nature of the strata and other causes. On two occasions when the writer visited No. 2 caisson or shaft, the supply of air was estimated at about 50 and 100 cubic feet per minute for the four persons usually employed. The smaller quantity was supplied when the bottom of the shaft was in very tough boulder-clay, and there was, it may be imagined, but little percolation other than that which occurred through the material-lock. When the sinking was in sand or water-bearing strata, considerable percolation took place through the strata, and probably upward around the outer skin of the caisson. Further escapes of air happened each time that either of the locks was opened for the passage of débris or men. During this operation, the lock was filled with air from the inside of the caisson, the air thus displaced being replaced by fresh air admitted to the caisson through the check-valve on the supply-pipe, direct from the air-compressor.

Owing to the proximity of the steam-boiler to the air-compressor on the surface, the temperature of the air at an early stage of the sinking operations was unnecessarily high; and, owing to compression, the air became warmer still inside the caisson, so warm indeed that, on coming out of the lock, during the early months of the year, the workmen felt the change of temperature very keenly. In fact, it was deemed advisable, when leaving the caisson, for the men not to pass out of the lock too quickly, so as to cool down, as it were; and afterwards to take a drink of hot coffee, so as to avoid taking cold.

Later on, a partition, erected between the steam-boiler and the air-compressor, reduced the temperature; and, about the middle of July, 1905, when No. 1 shaft was 75 feet deep, the temperature in the shade was 69° Fahr.; at the air-compressor, 71° Fahr.; and inside the air-lock after compression, 76° Fahr., the increase of 5° Fahr. being due to compression. At the bottom of the shaft, the temperature was 68° Fahr.; and the warm air condensing at the top, drops of water were constantly falling to the bottom of the caisson.

There was practically no blasting. The pit-bottom was lighted by an electric lamp of 16 candlepower, the top of the caisson being similarly lighted. Under these conditions, with the percolation referred to always present, the air at the bottom of the caisson was maintained in an apparently fresh and cool condition, at a time when the maximum pressure was about 22 pounds per square inch. In fact, so far as ventilation was concerned, the shafts might, if found necessary, have been sunk deeper with little difficulty.

TABLE III.—TEMPERATURE OF AIR, ETC., AT NO. 2 SHAFT.

Place of Observation.	Temperature.	Air-pressure per Square Inch.	Air-supply per Person per Minute.	Carbon Dioxide.
	Degs. Fahr.	Pounds.	Cubic Feet.	Per cent.
Shade	53	—	—	—
Air-compressor, inside shed ...	66½	—	—	0·05
Inside caisson:				
Top of shaft	72	16½	100	—
Bottom of shaft	58½	16½	—	0·10

On October 5th, 1905, when No. 2 caisson or shaft was 80 feet deep, samples of compressed air at the shaft-bottom were taken by Mr. Forsyth and the writer, and for comparison a sample was also taken of the air entering the compressor at the surface. By the kindness of Mr. Charles Latham, Dixon Lecturer on Mining, these samples were analysed at Glasgow University, and the results, along with the writer's own observations as to temperature, etc., are recorded in Table III. Pure air contains from 0·03 to 0·04 of carbon dioxide. The difference between this and the air at the Ardeer compressor was no doubt due to the proximity of the boiler-fires, the larger difference between 0·05 and 0·10 being the vitiation caused by the breathing of the workmen.

In tunnel-work (the Greenwich subway, for instance), Dr. A. H. Macmorran said that as much as 0·19 or 0·21 per cent. of carbon dioxide was found.* So, in comparison with this, the air in the shafts at Ardeer was satisfactory. In driving the Greenwich subway, a scrubber containing caustic soda was employed to remove the carbon dioxide from the air; but a blow-out pipe appears to have been the more effective device.

In order to keep the percentage of carbon dioxide as low as possible, experience at Ardeer points to the necessity of placing the steam-boilers as far as may be from the air-compressors, so as to prevent contamination of the air in the vicinity of the air-compressor, and to avoid, by this means and by the use of a water-jacket on the air-compressor, sending the air into the caisson at an unnecessarily high temperature. In fact, in order to secure cold and clean air during the suction-stroke of the air-compressor, it is desirable to draw the air-supply from a point outside of the engine-house. Given these conditions, in the absence of blasting and thanks to the use of the electric light, there seems little difficulty in ventilating a caisson or shaft sunk to moderate depths; although with increased pressure it might probably be necessary to vary the position of the inlet, in order to distribute the air throughout the compressed-air chamber and to provide an outlet-pipe, where the percolations proved insufficient to dispel the vitiated air.

It is generally recognized that an excess of carbon dioxide in the air and a limited air-supply are two of the principal factors in compressed-air illness. It follows, therefore, from this relationship that close attention must be paid to the ventilation of the compressed-air chamber.

This point may be further emphasized by the following remarks made by Mr. A. H. Haigh on the construction of the Baker Street and Waterloo tunnel:—†

> It had been found that when 130,000 cubic feet of air per hour were being driven through, which provided more than 8,000 cubic feet per man per hour, the sickness had been very slight, scarcely any cases for medical treatment having occurred; but when only 1,300 cubic feet to 2,000 cubic feet per man per hour were being driven, with a clay-face, the majority of the cases had occurred. Dr. [Frederick R.] Wainwright, the medical officer appointed by the contractors to

* *Minutes of Proceedings of the Institution of Civil Engineers*, 1902, vol. cl., page 43.

† *Ibid.*, 1901, vol. cxliv., page 107.

attend at the works, had found during his observations of the percentage of carbonic acid in the atmosphere, that, when driving the larger quantity of compressed air through the tunnel, the percentage of carbonic acid present had been between 0·06 and 0·07. When driving only between 1,300 cubic feet and 2,000 cubic feet of air per man per hour the percentage of carbonic acid had been between 0·08 and 0·10. The difference between the two had been due to the difference in the nature of the tunnel-face. The material in the ballast had been so open, that when a small area had been exposed for setting back the timbers the air had escaped so freely, that it had been impossible to keep the pressure up without driving through that large quantity of air; whereas in clay as much air could not be driven through the tunnel as had been desired, because it had been difficult to get the men to keep open the blow-out pipe provided for that purpose.

History of the Use of Compressed Air for Sinking.—The use of compressed air for power and for mechanical purposes antedates the use of steam by many years. It has long been used in various ways, in quarries and in mines. It is interesting to note in passing that, even for blasting, experiments were made at Wigan and elsewhere nearly 30 years ago. A very high pressure was obtained in these trials, and, as compared with powder, there was a saving of time and improved health of the men; but, as the cost of production exceeded that of explosives, the idea of blasting with compressed air was abandoned.

Compressed air has, however, within the last 75 years been often used in the sinking of caissons, for bridges, shafts, and in the construction of tunnels. The most recent works of the kind, having local interest, are as follows:—The Forth Bridge, where six caissons varying in depth from 63 to 89 feet were sunk between 1887 and 1890. The Glasgow subway in 1893 and 1894.* The Glasgow bridge in 1895; and more recently the Greenwich footway, where two shafts were sunk to depths of 60 and 66 feet respectively.† And this year, at Aberdeen, where a tunnel is being constructed under the river Dee, two shafts, a month or two ago, had attained depths of 53 and 62½ feet respectively.

In 1868, some shafts were sunk at Trazegnies, in Belgium, the maximum pressure being 3·12 atmospheres. Again, at the Maria colliery, near Aix-la-Chapelle, shafts were sunk by means of iron-tubbing and compressed air through a quicksand, 121 feet thick, the air-pressure being 3·2 atmospheres.‡

* "Tunnelling in Soft Material, with Special Reference to the Glasgow District Subway," by Mr. Robert Simpson, *Transactions of the Institution of Engineers and Shipbuilders in Scotland*, 1896, vol. xxxix., page 129.

† "The Greenwich Footway Tunnel," by Mr. W. C. Copperthwaite, *Minutes of Proceedings of the Institution of Civil Engineers*, 1902, vol. cl., page 1.

‡ *Trans. N.E. Inst.*, 1887, vol. xxxvi., abs. page 35.

In the sinking of shafts, for mines, the pneumatic process has rarely been adopted in Great Britain. The first operation of the kind appears to have been that of the Bettisfield colliery, in North Wales, where a shaft was sunk by Prof. Arnold Lupton to a depth of 102 feet.*

Another case, known to the writer, is that of a Stirlingshire coal-pit, which, a few years ago, was sunk to a depth of 120 feet. No record of the operation, however, seems to have been published.

Compressed-air Illness.—In 1861, during the construction of the Royal Albert bridge at Saltash, England, where the reported maximum air-pressure was 40 pounds per square inch above the atmosphere, the men through working too long a shift became slightly paralysed. But, with shifts of 3 hours' duration, the men could remain at such work for several months. Five years later, Dr. A. Magnus, of Königsberg, stated, as the result of his experience of the effect on men of the use of compressed air, that "the human organism may endure a pressure of four atmospheres without harm, but it frequently happens that sickness is caused by a rapid diminution of pressure."

One of the largest works, although not the earliest, constructed by the aid of compressed air was the sinking of the piers in connection with the St. Louis bridge over the Mississippi river. According to the history of that undertaking very little was then known of the peculiar effects of compressed air upon men engaged where it was employed. Twenty years earlier, Mr. J. Hughes, an engineer at the Rochester bridge in England, had noticed that men at work in compressed air had a remarkable increase of appetite for food; that respiration was slightly affected; and that, when transit through the air-lock was too rapidly made, headache resulted.

The word "bends" as applied to compressed-air illness appears to have originated during the construction of the St. Louis bridge, where, when workmen were seen walking with a difficult step and a slight stoop, they were regarded as a fit object for jokes, and such cases became known as the "Grecian bend."

Symptoms and Hygiene of Compressed Air.—Symptoms vary in degree and number in different individuals, but the most usual

* *Mining: an Elementary Treatise on the Getting of Minerals*, by Mr. Arnold Lupton, 1904, page 135.

effects upon workmen appear to be occasional muscular paralysis of the lower limbs, which generally passes off in a day or two. Those who have passed through an air-lock may have experienced pains in the ears, as the writer has, but this is usually cured by compressing the nostrils, and blowing out the drums of the ears. At the St. Louis bridge, when the depth increased beyond 60 feet, the paralysis became more difficult to subdue, and, in some cases, arms, muscles and bowels were involved. When the immersion became 65 feet to 93⅓ feet, two deaths occurred from apoplexy; and it was noted by Dr. Jaimet that, as the workers came from the air-chamber, their appearance was pallid and cold. In some, the pulse was quick, varying from 95 to 110 per minute, and somewhat weak; and with others it was as low as 60. Dr. Jaimet, moreover, observed that the pulse quickened on entering the air-chamber, although it soon fell to the normal pitch, and even lower at the end of the shift. On one occasion, with a pressure of 32½ pounds per square inch above that of the atmosphere, the pulses of himself and five other visitors before entering were 81, 78, 78, 79, 79 and 80: the temperature of the external air being 56° Fahr. After six minutes' duration in the air-lock, the pulses were 106, 88, 98, 86, 95 and 90: the temperature of the air being 62° Fahr. At the end of 2 hours inside the air-chamber, the pulses were 68, 70, 69, 71, 68 and 72. Before ascending the stairs, the pulses were 69, 70, 69, 71, 68 and 72; and, afterwards, they were 106, 104, 92, 94, 102 and 99. On another occasion, when the caisson touched the rock, and there was a pressure of 45 pounds per square inch above that of the atmosphere, a stay of 2¾ hours produced pain in the head, paralysis and loss of speech for 12 hours, and feebleness for some days. The highest pressure worked under at the undertaking was 50 pounds per square inch, and this pressure continued for several days. At the St. Louis bridge, where 600 persons were employed, there appeared to have been 119 cases of compressed-air illness, resulting in 14 deaths and in the permanent crippling of 2 workmen. These cases created great interest and discussion in medical and scientific circles, and the physicians were not agreed as to the action of the compressed air in producing the symptoms observed. One authority stated that the increased pressure upon the surface of the body compressed the superficial vessels, and forced the blood upon the

interior organs of the body, causing congestion; while another authority contended that the men were poisoned by carbon dioxide, abnormally retained within the system while in the air-chamber, and set free as soon as the pressure was removed. Another authority said that the men were sick from physical exhaustion, caused mainly by rapid waste of the system, which in the opinion of this particular physician, went on four times as fast under a pressure of four atmospheres as it did under the normal pressure.

In a paper on subaqueous tunnelling through the Thames gravel, by Mr. A. H. Haigh, Dr. Frederick R. Wainwright's experience is recorded.* Out of 120 men who were employed for 157 days, during which the range of air-pressure varied from 24·32 pounds per square inch above the normal, 88 men had previously worked in compressed air and 32 men had had no previous experience of it. Forty-seven cases of illness came under treatment, occurring among 40 different men: 2 men had three, and 3 men had two attacks. Dr. Wainwright was of opinion that none escaped a slight twinge of pain at some time or other.† The pathological effects of compressed air, as manifested during the work, were of two kinds. The minor effects were the direct result of the actual mechanical pressure during the change in the air-lock, the more serious effects, the real "bends," as they are called, were due to other causes, appeared some time after egress, and only after a lengthy stay in the compressed atmosphere. The symptoms of the former are chiefly pains in the ears and slight bleeding from the nose; and, of the latter, pain usually in the joints, often very severe.

The symptoms vary in degree and number in different individuals, and the theory advanced to account for the effects of compressed air on the human body have been classed by Dr. E. H. Snell as follow:—(1) Theories suggesting exhaustion, carbon-dioxide poisoning, and the like, as the cause; (2) theories ascribing the symptoms to the mechanical congestion of different viscera; and (3) theories depending on an increased solution by the blood of the gases of the compressed air, and the liberation

* *Minutes of Proceedings of the Institution of Civil Engineers*, 1902, vol. cl., page 38.

† "Observations on Compressed-air Illness," by Dr. Frederick R. Wainwright, *The Lancet*, 1900, vol. ii. for 1900, page 1792.

of these gases on the pressure being removed. The decision as to which of these theories is correct may be safely left in the hands of medical men; but suffice it to know that the illness is due to the absorption of air through the surface of the skin, the mucous membrane and the lungs. It behoves one, therefore, in sinking operations, by compressed air, to keep that air as pure as possible.

The Maximum Safe Pressure.—It seems that it is unsafe for some individuals even to enter compressed air; although some authorities on the subject state that, as a rule, working in a pressure not exceeding three atmospheres is not deleterious.* It has been recorded by Mr. Robert Simpson that, where the pressure was 30 pounds, "there were a great many cases of illness, and it was sometimes curious and sad to see the men, when they should have been at home in bed, coming back to the tunnels to get under the air in order to be relieved from their pain."† At this time, the men appear to have worked shifts of 8 hours, and were 3½ hours at a time in the compressed air; and, towards the end of the work, when the pressure was about 32 pounds (slightly above two atmospheres), there were 2 deaths and numerous cases of paralysis. Unfortunately, in the absence of an analysis of the air, it is impossible to form any opinion as to whether or not these cases might or might not be attributable to the percentage of carbon dioxide in the air itself.

In the case of the Redheugh bridge, where cylinders, 12 feet in diameter, were sunk to depths ranging from 65 feet to 79 feet below high-water level, Mr. J. M. Moncrieff‡ stated that:—

> The number of men employed in regular work in the working-chamber in sinking these cylinders had been about nine, and of these all except one had been more or less affected with "bends" and vomiting. Three cases of severe temporary paralysis had occurred, but of these one man had been physically unfit and had been only once under pressure, and that for a short time. He had not been examined by a medical man before entering the cylinder. Two of the men still

* *Minutes of Proceedings of the Institution of Civil Engineers*, 1901, vol. cxliv., page 107.

† "Tunnelling in Soft Material, with Special Reference to the Glasgow District Subway," *Transactions of the Institution of Engineers and Shipbuilders in Scotland*, 1896, vol. xxxix., page 129.

‡ *Minutes of Proceedings of the Institution of Civil Engineers*, 1901, vol. cxliv., page 136.

suffered slightly from bends. Only one case of illness occurred with the pressures under 20 pounds; but when the pressure had risen to between 30 and 34 pounds, three cases, two of them severe, had occurred in three days, after which the men had not worked when the pressure was above 30 pounds, which had been possible by ceasing work while the tide was high. The quantity of air supplied per man had also been largely increased, with good results, but he could not give any precise figures as to this. Under the lower pressures, the gangs had worked in shifts of 9 hours, divided into three sections of 2 hours' work in the cylinder and 1 hour of rest. With pressures between 26 and 30 pounds, the men had worked in shifts of 7 hours, divided into two sections of 3 hours' in the cylinder and 1 hour of rest between.

The writer noted in speaking, in the shafts at Ardeer, with a pressure of 22 pounds, that the tongue moved stiffly, and there was a disposition to lisp; but there was little or no alteration in the pulse, except that occasioned by descending and ascending the vertical rope-ladder from the bottom of the shaft to the air-lock.

With a pressure of 30 pounds, according to Mr. Gardner D. Hiscox,* men ascending caisson-ladders were much less out of breath than with the same work in the open air; sounds were not heard with the usual intensity, and the most usual affection was muscular pains. When, through lack of proper ventilation, the air became impregnated with lamp-smoke and carbon dioxide from respiration, all the pathogenic conditions became intensified, and under a pressure of 40 to 50 pounds per square inch, taste, smell and touch lost their acuteness. During the time when the pressure was increasing, hearing was affected, with a feeling of increased warmth in the skin as if going into a warm room. Mr. Hiscox states that, while the pressure remained stationary, all subjective phenomena disappeared, to return again during locking out from the caisson, taste and smell returned, and a prickling sense of warmth was felt in the nostrils, sometimes followed by bleeding at the nose. At the same time, rapid decline of temperature from the expansion of the air caused extreme chilliness on going out from a caisson. Intense pains in the ears and muscles sometimes occurred, but they were much modified or avoided by enforcing a slow change of pressure.

The wellknown factors, governing the occurrence of compressed-air illness, are as follow:—(1) The physical state of the worker; (2) the rapidity or otherwise of entering, and more

* *Compressed Air*, by Mr. Gardner D. Hiscox.

especially of returning out of the compressed air; (3) the amount of pressure; (4) the condition and quantity of the air supplied into the chamber; and (5) the length of the shift worked.

Dealing now with these factors in detail:—(1) At Ardeer, it was not thought necessary by the contractors to have the men medically examined. Healthy-looking subjects, however, were chosen; and, fortunately, the only cases of sickness occurred to two sinkers who complained of pains in the joints, and, after seeking medical advice, they returned to work after the lapse of two or three shifts. Another man bled at the nose, a visitor spat blood, and another was partly deaf for a week. It must, however, be borne in mind that, as these factors react on one another, the necessity for medical examination probably depends upon the air-pressure that the worker has to undergo. That is to say, that while it might be safe to admit workers at moderate pressures of 20 pounds per square inch, above that pressure the safer plan would be to have all workers medically examined beforehand.

(2) The speed of locking was regulated by the workers themselves, as the cock by which the compressed air was admitted to the air-lock was under their own control; and, consequently, the compressed air could be put on somewhat rapidly or the reverse. The men at Ardeer were allowed 10 minutes for coming out of the caisson, and, judging by the writer's experience, if the time were wholly absorbed in the process, there would be less risk of taking cold on coming out, and less risk of pain when going in, even under higher pressure.

(3) The maximum working-pressure at Ardeer never exceeded 26 pounds per square inch: this pressure being only a little over half of that employed in connection with the St. Louis bridge and other undertakings. It is no doubt desirable to avoid high pressures when possible, and this has been done by simply throwing out the water as it collected at the pit-bottom. Mr. A. S. Biggart,* referring to a case where a cylinder was sunk to a depth of 130 feet, stated that, by simply throwing out the water through a pipe by means of air-pressure, the pressure (which otherwise might have been as high as 45 to 50 pounds) was

* *Transactions of the Institution of Engineers and Shipbuilders in Scotland*, 1896, vol. xxxix., page 160.

reduced to about 15 pounds per square inch. This plan is evidently the idea of the air-lift pump, and it was practised in the sinking of the shaft at Ardeer.

(4) The remarks under the head of ventilation shew that, at Ardeer, the air at the bottom of the caisson was maintained in a fresh and cool condition. They also shew how these results were obtained. It has been recorded in similar undertakings that the burning of candles, etc., combined with high pressure and the absence of percolation when in mud instead of sand, may have had something to do with the illness of the men. The writer thinks that there can be no doubt that such was the case, and that the use of electric lamps in place of open lights had effected considerable improvement in the air.

(5) The sinkers in the shafts, at Ardeer, worked from 54 to 55 hours per week. The day-shift began at 6 a.m. and terminated at 5 p.m., 1¼ hours were allowed for meals, and 9 to 10 minutes, each time, for coming out of the shaft. The night-shift extended from 5·45 p.m. to 5·45 a.m., with intervals for meals, so that the workers were never more than 4 hours or so in the compressed air at any time. With a pressure not exceeding 23 pounds, and the condition of the air being good, workers physically fit appear to be able to work with a fair degree of comfort for 4 hours at a stretch.

It is evident from the foregoing remarks that:—(1) The workers should be physically sound and well fed. (2) When entering into and returning from the working chamber, the proceeding should be gradually accomplished, the pressure not being increased or decreased more quickly than, say, 4 pounds per minute. In the event of any person, when entering the chamber, suffering pain, which cannot be removed by compressing the nostrils and blowing out the drums of the ears, the pressure should be gradually reduced, and that person sent out of the caisson. (3) The air should be maintained in a fresh state by distribution, percolation and other means. (4) As the pressure increases, the length of the workers' shift should decrease.

Mr. W. C. Copperthwaite, bridges engineer to the London County Council, has supplied the writer with several clauses (Appendix IV.) bearing upon the use of compressed air, taken from the specification for the Rotherhithe tunnel, now in course of construction.

Curative Treatment.—It remains to be added that, if the sickness be taken in time, recompression is sometimes resorted to, the patient being allowed to return to the normal pressure gradually, or in about 45 minutes. In extreme cases, Dr. E. H. Snell has used morphia, ergot and other drugs hypodermically, and also stimulating liniments containing aconite and belladonna, while relief has been given by the application of moderately tight bandages to the painful parts.

Wherever compressed air is going to be extensively used, a small hospital is usually provided, but at Ardeer no such steps were found necessary.

At the risk of repetition, the writer has gone further than he originally intended into the question of compressed-air illness. He has done so, not because the experience of Ardeer sinking demanded it, but simply because the method of sinking shafts by compressed air has not often been adopted by mining engineers. In view of other shafts requiring to be sunk near the sea in the future, the particulars may be of interest to some members who have practised methods other than compressed air, and may be called upon to sink through similar strata again.

In conclusion, it may be stated that the maximum air-pressure, in which work may be prosecuted with impunity, is not exactly known. There is, however, the case of the St. Louis bridge, where a pressure of 50 pounds per square inch was encountered, but the shifts had to be reduced to one hour each. The writer does not know the condition of the air at that pressure, but he believes that it is generally accepted that a man at rest requires about 50 cubic feet of air per minute, if his apartment is not to contain more than 0·06 per cent. of carbon dioxide. It follows, therefore, that if a person were required to perform heavy work, he would require several times more than this volume of air. Dr. E. H. Snell estimated this volume at 150 cubic feet per minute, and the writer thinks that, if 100 cubic feet were maintained and properly distributed, the ventilation might be, and probably would be, adequate. But this result would not obviate the necessity of reducing the length of the shift worked as the pressure increases; though possibly it

would afford a means of lengthening it, in comparison with working at a similar depth where the air-supply is not so good.

The writer is indebted to Mr. Robert Main for permission to give the particulars of the sinkings at Ardeer and to use the illustrations accompanying this paper; to Mr. John Muir, colliery manager, and to Mr. A. L. Forsyth, colliery surveyor, for their valuable assistance, and for the necessary information relating to the progress of the sinking operations carried out so successfully under the latter's daily supervision.

APPENDIX I.—SECTION OF STRATA PASSED THROUGH IN No. 5 BORE-HOLE AND No. 2 CAISSON OR SHAFT.

No.	Description of Strata.	Thickness of Strata. Ft.	Ins.	Depth from Surface. Ft.	Ins.
1	Dry sand	28	0	28	0
2	Wet sand	30	0	58	0
3	Wet sand, with a few shells	11	6	69	6
4	Gravel	2	0	71	6
5	Muddy clay, with stones	10	0	81	6
6	Stiff clay, with boulders	10	0	91	6
7	Green sandstone	0	11	92	5
8	Green fakes	2	0	94	5
9	Green and red blaes	2	3	96	8
10	Green sandstone	0	9	97	5
11	Green fakes	4	0	101	5
12	Green sandstone	3	1	104	6
13	Light coloured calmy fakes and blaes	3	6	108	0
14	Dark coloured blaes	10	0	118	0
15	Light coloured calmy blaes	5	6	123	6
16	Blaes of various colours	3	9	127	3
17	Greenish fakes	2	6	129	9
18	Greenish sandstone and fakey plies	3	6	133	3
19	Green fakes	1	6	134	9
20	Green sandstone	1	6	136	3
21	Red and brown blaes	2	9	139	0
22	Dark coloured blaes	2	6	141	6
23	Greenish fakes and sandstone	3	6	145	0
24	Blaes of various colours	1	6	146	6
25	Greenish fakes	1	9	148	3
26	Fakes and blaes	1	3	149	6
27	Blaes of various colours	14	8	164	2
28	Light coloured calmy fakes	1	9	165	11
29	Sandstone	0	6	166	5
30	Calmy fakes and hard ribs	2	6	168	11
31	Light coloured sandstone	1	9	170	8
32	Black blaes	0	7	171	3
33	COAL	0	4	171	7
34	Dark blaes	2	7	174	2
35	Light blaes	12	11	187	1
36	Calmy fakes	1	0	188	1
37	White sandstone, with traces of *coal*	3	4	191	5
38	Fakes	1	0	192	5
39	Sandstone, with strains of *coal*	3	0	195	5
40	Fakes and blaes	3	6	198	11
41	Sandstone	2	3	201	2

APPENDIX II.—JOURNAL OF THE SINKING OF No. 1 CAISSON OR SHAFT, ARDEER.

,,	5	,, ..	..	..	2	0	8	0	5	No excavation from December 5th to 10th, so as to allow caulkers to caulk the caisson.
,,	10	,, ..	..	..	3	0	11	0	6	
,,	12	,, ..	..	..	1	0	12	0	6	
,,	13	,, ..	..	..	0	3	12	3	6	
,,	14	,, ..	..	..	..		..		..	No one at work.
,,	15	,, ..	..	..	1	6	13	9	8	
,,	16	,, ..	..	..	1	9	15	6	4	
,,	17	,, ..	..	..	2	3	17	9	5	Level of water. From December 17th, employed in fitting engine, etc., on the surface.
1905. Feb.	18	Wet sand ..	19	0	0	9	18	6	4	Commenced to use compressed air.
,,	20	,, ..	75	0	1	11	20	5	4	
,,	21	,, ..	87	0	1	2	21	7	4	
,,	,,	,,	101	0	0	5	22	0	4	
,,	22	,, ..	98	0	1	10	23	10	4	
,,	,,	,, ..	15	0	2	6	26	4	4	
,,	23	,, ..	89	0	0	4	26	8	4	
,,	,,	,, ..	76	0	1	6	28	2	4	
,,	24	,, ..	97	0	2	4	30	6	4	
,,	,,	,, .	80	0	0	9	31	3	4	60 tons of pig-iron placed on the caisson.
,,	25	,, .	93	0	0	11	32	2	4	
,,	,,	,, ..	45	0	3	10	36	0	4	Average air-pressure during sinking, 7 pounds. From February 25th, until March 14th, occupied in shifting deck, locks, etc., from No. 1 to No. 2 caisson.
April	5	,, .	18	0	0	0	36	0	4	
,,	6	,, ..	92	0	0	0	36	0	4	
,,	,,	,, ..	76	0	0	0	36	0	4	
,,	7	,, ..	82	0	1	6	37	6	4	
,,	,,	,, .	80	0	0	0	37	6	4	
,,	8	,, ..	71	0	2	9	40	3	4	
,,	,,	,, ..	43	0	1	3	41	6	4	
,,	9	,, .	84	0	1	6	43	0	4	
,,	10	,, ..	94	0	1	6	44	6	4	
,,	,,	,, ..	84	0	0	0	44	6	4	
,,	11	,, ..	71	0	2	3	46	9	4	
,,	,,	,, ..	26	0	0	0	46	9	4	
,,	12	,, .	101	0	2	2	48	11	4	
,,	,,	,, ..	80	0	0	0	48	11	4	
,,	13	,, ..	80	0	1	4	50	3	4	
,,	14	,, ..	46	0	0	0	50	3	4	Loading caisson with 60 tons of pig-iron, and putting in stays to bring it back to the plumb-line, if possible.
,,	15	,, ..	..	0	0	0	50	3	.	
,,	16	,, .	..	0	0	0	50	3	..	
,,	17	,, ..	..	0	3	9	54	0	..	Average air-pressure during sinking, 14 pounds. From April 17th to April 24th, employed in shifting deck, locks, etc., to No. 2 caisson.
May	21	Wet sand and shells	..	..	..		54	0	..	
,,	22	,,	86	0	0	0	54	0	4	
,,	,,	,,	85	0	0	0	54	0	4	
,,	23	,,	68	0	1	6½	55	6½	4	
,,	24	,,	62	0	0	11¼	56	5¾	4	
,,	,,	,,	86	0	0	0	56	5¾	4	
,,	25	,,	..	..	0	11½	57	5¼	..	
,,	26	Gravel ..	90	0	0	0	57	5¼	4	
,,	,,	,, .	81	0	0	0	57	5¼	4	
,,	27	,, ..	68	0	0	8½	58	1¾	4	A depth of 2 feet of water came in while caisson was sinking.
,,	28	Muddy clay and stones	46	0	0	0	58	1¾	4	
,,	29	,,	86	0	0	7	58	8¾	4	A depth of 2 feet of water came in while caisson was sinking.
,,	,,	,,	55	0	0	0	58	8¾	4	
,,	30	,,	5	0	0	0	58	8¾	4	
,,	,,	,,	22	0	0	0	58	8¾	4	
,,	31	,,	43	0	0	9½	59	6¼	4	A depth of 1½ feet of water came in while caisson was sinking.
,,	,,	,,			..		59	6¼	..	No one at work, owing to water in caisson.
June	1	,,	31	7	0	0	59	6¼	4	
,,	2	,,	53	13	0	2½	59	8¾	4	

APPENDIX II.—No. 1 SHAFT.—*Continued.*

Date.			Buckets.	Buckets.	Ft.	Ins.	Ft.	Ins.	No.	
1905. June	2	Muddy clay and stones	30	[illegible]	0	0	59	8½	4	
"	3	"	..	..	..	..	59	8½	..	Loading caisson with pig-iron.
"	4	"	..	..	0	4½	60	1¼	..	Loading caisson with pig-iron.
"	5	"	9	22	0	0	60	1¼	4	
"	"	"	33	0	0	0	60	1¼	4	200 tons of pig-iron on.
"	6	"	33	24	0	3	60	4¼	4	
"	"	"	33	22	0	0	60	4¼	4	
"	7	"	33	22	0	1¼	60	5½	4	
"	"	"	33	18	0	1¾	60	7¼	4	
"	8	"	33	20	0	3½	60	10¾	4	
"	"	"	36	6	0	0	60	10¾	4	
"	9	"	38	12	0	0	60	10¾	4	
"	"	"	33	7	0	0	60	10¾	4	
"	10	"	21	25	0	1¼	61	0	4	1½ pounds of saxonite were fired at 7 p.m. and caisson settled down 1¼ inches.
"	11	"	..	..	..	..	61	0	..	Air off, and no one at work.
"	12	"	..	..	0	6½	61	6½	..	Caisson settled down 6½ inches, while taking off pig-iron when air was off
"	24	"	45	22	0	1	61	7½	4	Taking off pig-iron from 13th to 24th.
"	25	"	..	..	0	0¾	61	8¼	..	Putting on two large girders, sixteen H beams and 550 tons of pig-iron.
"	26	"	0	63	0	0	61	8¼	.	Started engine on June 26th, and with 31 pounds pressure blew 36 feet of water outside of the caisson.
"	"	"	36	0	4	3¼	65	11½	4	
"	27	"	63	5	0	0	65	11½	4	
"	"	"	33	0	0	0	65	11½	4	
"	28	"	33	0	0	0	65	11½	4	
"	"	"	36	2	2	4½	68	4	4	
"	29	"	58	4	0	4	68	8	4	
"	"	"	39	1	0	2½	68	10½	4	
"	30	"	60	0	0	0	68	10½	4	
"	"	"	43	0	0	0	68	10½	4	
July	1	Stiff clay	42	0	0	0	68	10½	4	
"	"	"	10	0	0	0	68	10½	4	Engine standing for 30 hours; only 7 buckets of water came in while clearing round the caisson for piles.
"	2	"	31	7	0	0	68	10½	4	
"	3	"	34	9	1	7½	70	6	4	Two shots fired, but they did no good.
"	"	"	28	0	0	0	70	6	4	
"	4	"	33	0	0	0	70	6	4	
"	"	"	35	0	0	0	70	6	4	
"	5	"	26	0	1	3	71	9	4	
"	"	"	36	0	0	0	71	9	4	
"	6	"	32	0	1	1	72	10	4	
"	"	"	40	1	0	0	72	10	4	
"	7	"	33	0	0	11	73	9	4	
"	"	"	37	1	0	0	73	9	4	
"	8	"	12	1	1	5	75	2	4	
"	9	"	60	0	0	0	75	2	4	
"	10	"	35	0	1	5	76	7	4	600 tons of pig-iron placed on the caisson.
"	"	"	40	0	1	1¾	77	8¾	4	
"	11	"	26	0	1	0	78	8¾	4	Average air-pressure, 19 pounds.
"	"	"	33	0	0	0	78	8¾	4	
"	12	"	26	0	0	0	78	8¾	4	Two box-girders broke at 7 p.m. From July 12th to 30th, engaged in taking off pig-iron, H beams, deck and locks from No 1, and putting deck and locks on to No. 2 caisson.
Aug.	21	"	87	50	0	0	78	8¾	..	Open-cast sinking in No. 1 shaft. The buckets used in the open sinking were barely half the size of the other buckets.
"	22	"	74	50	0	0	78	8¾	..	
"	"	"	81	60	0	0	78	8¾	.	
"	23	"	79	46	0	0	78	8¾	..	
"	"	"	84	43	0	0	78	8¾	..	
"	24	"	73	77	0	0	78	8¾	..	
"	"	"	49	130	0	0	78	8¾	.	
"	25	"	43	109	0	0	78	8¾	..	The water trickling in below the cutting-edge had worn two holes outside the caisson, about 3 feet long, 1 foot wide and 2 feet high. These holes were filled with straw, bags and clay, and all excavation was stopped.
Sept.	23	"	..	..	..	..	..	..	..	Engine started.
"	25	"	0	59	0	2	78	10¾	..	Putting pig-iron upon caisson.
"	26	"	0	82	0	0	78	10¾	..	Putting pig-iron upon caisson

APPENDIX II.—No. 1. SHAFT.—*Continued.*

Date.		Description of Strata.	Material excavated.	Water drawn.	Depth sunk.		Depth from Surface.		Workmen employed in Caisson per Shift.	Remarks.
			Buckets.	Buckets.	Ft.	Ins.	Ft.	Ins.	No.	
1905.										
Sept.	27	Stiff clay ..	0	86	0	0	78	10¾	..	Putting pig-iron upon caisson.
,,	28	,, ..	0	90	0	1	78	11¾	..	Putting pig-iron upon caisson.
,,	29	,, ..	0	39	0	0	78	11¾	..	Putting pig-iron upon caisson.
,,	,,	,, ..	0	92	0	0	78	11¾	..	
,,	30	,, ..	0	40	0	0	78	11¾	..	Putting pig-iron upon caisson, a total of 450 tons.
Oct.	1	,, ..	0	84	0	0	78	11¾	..	
,,	,,	,, ..	0	88	0	0	78	11¾	..	
,,	2	,, ..	0	80	0	0	78	11¾	..	
,,	,,	,, ..	0	73	0	0	78	11¾	..	
,,	3	,, ..	0	82	0	0	78	11¾	..	
,,	,,	,, ..	2	63	0	0	78	11¾	4	
,,	4	,, ..	31	18	0	0	78	11¾	4	
,,	,,	,, ..	34	15	0	2½	79	2¼	4	
,,	5	,, ..	6	34	2	0	81	2¼	4	
,,	,,	,, .	2	73	0	0	81	2¼	4	Water coming through the clay from rock-head.
,,	6	,, ..	21	43	0	0	81	2¼	4	
,,	,,	,, ..	7	38	0	0	81	2¼	4	
,,	7	,, ...	9	9	0	10	82	0¼	4	Water stopped.
,,	8	,, ...	29	31	0	0	82	0¼	4	
,,	,,	,, ..	38	5	0	0	82	0¼	4	Struck rock-head.
,,	9	,, ...	37	3	0	0	82	0¼	4	
,,	,,	Green sandstone	35	6	0	0	82	0¼	4	
,,	10	,,	33	4	0	0	82	0¼	4	
,,	,,	,,	19	4	0	0	82	0¼	4	Air-pressure of 22 or 23 pounds.
,,	11	,,	17	6	0	0	82	0¼	4	Caisson 8 inches from plumb-line in 85 feet.
,,	,,	,,	11	5	0	0	82	0¼	4	
,,	12	..	..	..	3	0	85	0¼	..	Caisson level all round on rock. From October 12th to 16th, employed in taking out bevelled brickwork and building brickwork upward from the rock-head to the shelf. After the compressed air was taken off No. 1 caisson or shaft, the water off the rock rose at the rate of 1¼ gallons per minute. From October 16th to November 2nd, engaged in taking off the H beams, pig-iron, deck and locks from No 1, and putting them on No. 2 caisson or shaft.

APPENDIX III.—JOURNAL OF THE SINKING OF NO. 2 CAISSON OR SHAFT, ARDEER.

Date.		Description of Strata.	Material excavated.	Water drawn.	Depth sunk.		Depth from Surface.		Workmen employed in Caisson per Shift.	Remarks.
			Buckets.	Buckets.	Ft.	Ins.	Ft.	Ins.	No.	
1904										
Dec.	22	Loose sand..	..	..	3	0	3	0	6	
,,	23	,, ..	..	..	1	0	4	0	6	
,,	24	,, ..	..	..	5	0	9	0	5	
,,	27	,, ..	..	..	0	9	9	9	7	
,,	28	,, ..	..	..	0	9	10	6	7	
,,	29	,, ..	..	..	0	0	10	6	..	No men at work.
,,	31	,, ..	..	..	1	6	12	0	4	
1905										
Jan.	3	,, ..	..	..	1	0	13	0	4	
,,	4	,, ..	..	..	2	0	15	0	5	
,,	5	,, ..	..	..	2	9	17	9	5	Level of water. From January 5th, employed in fitting engine, etc., on surface.
Mar.	14	Wet sand..	47	0	0	0	17	9	4	
,,	15	,, ..	66	0	1	6	19	3	4	

APPENDIX III.—No. 2 SHAFT.—*Continued.*

Date.	Description of Strata.	Material excavated.	Water drawn.	Depth sunk.		Depth from Surface.		Workmen employed in Caisson per Shift.	Remarks.
		Buckets.	Buckets.	Ft.	Ins.	Ft.	Ins.	No.	
1905. Mar. 15	Wet sand ..	71	0	0	5	19	8	4	
" 16	" ..	..	..	0	0	19	8	..	No men at work.
" "	" ..	50	0	1	6	21	2	4	
" 17	" ..	80	0	2	3	23	5	4	
" "	" ..	74	0	2	1	25	6	4	
" 18	" ..	33	0	1	2	26	8	4	
" "	" ..	14	0	1	3	27	11	4	
" 20	" ..	70	0	0	5	28	4	4	
" 21	" ..	95	0	2	3	30	7	4	No pig-iron on the caisson. The average air-pressure was 7 pounds.
" "	" ..	77	0	1	3	31	10	4	
" 22	" ..	96	0	4	9	36	7	4	
									From March 22nd until April 5th, occupied in shifting deck, locks, etc., from No. 2 to No. 1 caisson or shaft.
April 24	" ..	8	0	0	0	36	7	4	
" 25	" ..	95	0	1	0	37	7	4	
" "	" ..	96	0	0	0	37	7	4	
" 26	" ..	103	0	2	2	39	9	4	
" "	" ..	71	0	0	0	39	9	4	
" 27	" ..	100	0	2	0	41	9	4	
" "	" ..	50	0	0	9	42	6	4	
" 28	" ..	90	0	1	2½	43	8½	4	
" "	" ..	74	0	0	0	43	8½	4	
" 29	" ..	101	0	1	4½	45	1	4	
" "	" ..	14	0	0	0	45	1	4	
" 30	" ..	65	0	1	8	46	9	4	
May 1	" ..	47	0	0	0	46	9	4	
" "	" ..	95	0	0	0	46	9	4	
" 2	" ..	105	0	1	6	48	3	4	
" "	" ..	84	0	0	8	48	11	4	
" 3	" ..	102	0	0	0	48	11	4	
" "	" ..	81	0	1	6	50	5	4	
" 4	" ..	103	0	1	4	51	9	4	
" 5	" ..	107	0	1	3	53	0	4	No pig-iron on the caisson.
" 6	" ..	..	..	1	3	54	3	..	Average air-pressure of 14 pounds.
									From May 6th to May 21st, employed in shifting deck, locks, etc., to No. 1 caisson or shaft.
July 31	" ..	0	63	0	0	54	3		
Aug. 1	" ..	54	10	0	0	54	3	4	
" "	" ..	90	0	0	0	54	3	4	
" 2	" ..	64	0	0	8¼	54	11¼	5	Caisson 3 inches from the plumb-line.
" "	" .	70	22	0	7	55	6¼	5	
" 3	" ..	24	33	0	0	55	6¼	5	
" "	" ..	88	0	0	10¼	56	4½	5	
" 4	" ..	65	0	0	0	56	4½	5	
" "	" ..	63	10	1	0½	57	5	5	
" 5	" ..	4	0	0	0	57	5	5	Putting H beams on caisson.
" 6	" .	66	2	0	0	57	5	5	Putting 20 tons of pig-iron on the caisson. Caisson now vertical.
" 7	Sand and stone	67	0	1	0	58	5	5	
" "	" ..	58	20	0	0	58	5	5	
" 8	" .	69	3	0	8½	59	1½	5	
" "	" ..	64	23	0	0	59	1½	5	
" 9	" ..	56	2	0	4	59	5½	5	
" "	" ..	51	30	0	0	59	5½	5	
" 10	" ..	36	4	0	4½	59	10	5	Putting pig-iron on the caisson. 170 tons now on.
" 11	Muddy clay	0	0	0	1½	59	11½	5	Putting pig-iron on the caisson.
" "	" ..	33	44	0	0	59	11½	5	
" 12	" ..	..	..	..		59	11½	..	Putting pig-iron on the caisson.
" 13	" ..	..	..	..		59	11½	..	Putting pig-iron on the caisson.
" 14	" ..	..	..	0	4	60	3½	..	Putting pig-iron on the caisson. 250 tons now on.
" "	" ..	40	18	0	0	60	3½	5	
" 15	" ..	23	7	3	4	63	7½	5	
" "	" ..	51	7	0	0	63	7½	5	Putting pig-iron on the caisson. 430 tons now on.
" 16	" ..	58	1	3	2	66	9½	5	
" "	" ..	73	2	0	0	66	9½	5	
" 17	" ..	66	0	0	0	66	9½	5	
" "	" ..	78	0	2	6½	69	4	5	
" 18	" ..	53	10	0	0	69	4	5	
" "	" .	49	0	0	0	69	4	5	
" 19	" ..	28	0	0	4	69	8	5	
" 20	" ..	62	3	0	0	69	8	5	

APPENDIX III.—No. 2 SHAFT.—*Continued.*

Date.	Description of Strata.	Material excavated.	Water drawn.	Depth sunk.		Depth from Surface.		Workmen employed in Caisson per Shift.	Remarks.
		Buckets.	Buckets.	Ft.	Ins.	Ft.	Ins.	No.	
1905.									
Aug. 21	Stiff clay ..	45	2	0	0	69	8	5	
" "	" ..	29	2	0	0	69	8	5	
" 22	" ..	36	1	1	3¼	70	11¼	5	
" "	" ..	32	3	0	0	70	11¼	5	
" 23	" ..	32	1	0	7	71	6¼	5	
" "	" ..	40	1	0	0	71	6¼	5	
" 24	" ..	33	2	1	1	72	7¼	5	
" "	" ..	51	0	0	0	72	7¼	5	
" 25	" ..	32	0	1	8	74	3¼	5	
" "	" ..	51	0	0	0	74	3¼	5	
" 26	" ..	18	0	1	2¼	75	5½	5	
" 27	" ..	50	0	0	0	75	5½	5	
" 28	" ..	42	0	1	5	76	10½	5	
" "	" ..	43	0	0	0	76	10½	5	
" 29	" ..	39	0	1	9½	78	8	5	
" "	" ..	48	0	0	0	78	8	5	
" 30	" ..	34	0	1	1	79	9	5	Taking out clay in the centre of the caisson down to the rock, leaving a wall of clay to support the caisson.
" "	" ..	46	0	0	0	79	9	5	Taking out clay in the centre of the caisson down to the rock.
" 31	" ..	41	0	0	0	79	9	5	" " "
" "	" ..	48	0	0	0	79	9	5	" " "
Sept. 1	" ..	43	0	0	0	79	9	5	" " "
" "	" ..	47	0	0	0	79	9	5	" " "
" 2	" ..	19	0	0	0	79	9	5	" " " Struck rock at 12 noon.
" 3	"	..	..	..		79	9	..	No men at work.
" 4	" ..	2	0	0	0	79	9	5	
" "	" ..	31	0	0	0	79	9	5	An average air-pressure of 19 pounds. From September 4th to 25th, engaged in shifting beams, pig-iron, deck and locks from No. 2 caisson to No. 1 caisson or shaft.
Nov. 2	" ..	13	5	3	7	83	4	5	500 tons of pig-iron on the caisson.
" 3	" ..	40	0	0	0	83	4	5	
" "	" ..	36	0	2	9	86	1	5	
" 4	" ..	58	0	0	0	86	1	5	
" "	" ..	34	0	1	4	87	5	5	
" 5	" ..	53	0	0	0	87	5	5	500 tons of pig-iron on the caisson.
" 6	" ..	67	0	0	0	87	5	5	Average air-pressure of 23 pounds.
" "	" ..	45	0	0	0	87	5	5	
" 7	Green sandstone and clay	60	0	3	0	90	5	5	Caisson level on rock for fully one half of the circumference and the remainder on clay, caused by a step or fault. From November 7th to 11th, employed in taking out bevelled brickwork, and building brickwork upward from the rock-head to the shelf. Water in No. 2 caisson was 1 foot deep, after standing a fortnight.

APPENDIX IV.—PRECAUTIONARY RULES, EXTRACTED FROM THE SPECIFICATION OF THE ROTHERHITHE TUNNEL.

26.—*Ventilation of Working-faces.*—The contractor shall, without extra charge, have all the working-faces properly ventilated, and the amount of carbonic acid gas present at any time shall not be allowed to exceed 0·08 per cent. A minimum of 8,000 cubic feet of free air per hour per man shall be pumped into the tunnel, and shall be brought to the working-face. When working in compressed air at the bottom of the caisson, similar conditions shall apply. The blow-out pipe shall be used at the working-faces, once at least in every hour. Suitable lifts and resting-places for the men, including a compressed-air chamber fitted with bunks, and a drying-room for clothes, must be provided. In all air-tight floors and bulkheads for the shafts and tunnel, a small emergency air-lock must be provided, in addition to the

ordinary working air-lock, with access thereto from the ordinary working-levels.

27.—*Electric Light and Telephone.*—The tunnel and shafts shall, without extra charge, be lighted by electric light during the progress of the works, and there must be telephonic communication between all parts of the works and the offices of the resident engineer; and, generally, the contractor shall provide every means and appliance which may in any way conduce to the safety of the works and the men employed on them. The contractor shall also, without extra charge, provide a private telephone wire and all apparatus for communication between the works and the engineer's offices, Spring-gardens.

28.—*Refreshments and Arrangements for Men.*—Whenever possible, each man coming out of the compressed-air chamber shall be provided with a cup of hot coffee, and arrangements shall be made that it shall not be necessary to climb any stairs immediately after coming out. Proper sanitary conveniences, in all respects satisfactory to the engineer, shall be made for the men working in the tunnel and shafts. The greatest care shall be taken that all portions of the work being carried out, whether under compressed air or otherwise, shall be kept in a thoroughly sanitary condition. The carrying-out of the whole of the conditions of this clause shall be considered as a contingency on the cost of the work.

29.—*Medical Officer.*—The Council may engage the services of a qualified medical practitioner to look after the well-being of the men employed; and, should they do so, the contractor shall, without extra charge, follow out all the reasonable instructions of the same from time to time.

30.—*Fitness of Men.*—No workman shall be engaged for the compressed-air work, without his fitness for such duties being proved by such medical examination as the Council may direct.

Mr. James T. Forgie (Bothwell) said that Mr. Mottram had written an excellent paper, describing a novel method of sinking through sand to a depth of 83 feet; it would be of interest to the members, and especially to those who apprehended any possibility of sinking through sand in the near future. There were several methods of sinking through sand, and, perhaps, the most successful of all had been the freezing process. It was a difficult matter to make comparisons as to cost, but he asked whether it would be possible for Mr. Mottram to give the members any idea of the cost of sinking by the caisson, as compared with the freezing process. To judge, however, from the information which Mr. Mottram had imparted in his paper, the cost could not be very low. A good deal of work seemed to be required in changing the air-locks from one pit to another, and the method of winding the material seemed to be slow and expensive. Could Mr. Mottram state the pressure used at the extreme depth of 83 feet?

Mr. T. H. MOTTRAM explained that the water collected at the bottom of the shaft was drained, by being blown through a pipe to the surface. The men were not working in the caisson at that time, and the pressure employed was about 26 pounds per square inch: the pressure being afterwards lowered, so as to avoid sinking under an unnecessarily high pressure.

Mr. CHARLES LATHAM (Glasgow) said that, along with Mr. Mottram, he had had the pleasure of visiting this sinking at Ardeer, and he was very much impressed with the easy way in which the system could be carried out. Comparing it with sinking by freezing, he could say, from his own experience, that not only was it the cheaper of the two methods, but that it was also the more satisfactory. The difference was most marked in a case where the water in the sand was apt to run into eddies or channels; and it appeared to him, in sinking by freezing, that there would be difficulty in freezing water of that particular kind; and there was also a difficulty in freezing salt water.

Extreme labour was involved in removing the pig-iron, from time to time, when it was found necessary to increase the length of the caisson. There seemed to him to be much unnecessary labour, which might be avoided, he thought, by putting some of the weights inside the caisson, so that, when it was necessary to take off the top, the whole of the weights need not be removed. A certain portion of the weight might be allowed to slide down along with the caisson, and be removed at a later period.

He (Mr. Latham) remembered Prof. Arnold Lupton describing his experience at the Bettisfield sinking, in North Wales. The great difficulty, there, arose from the workmen being unable to stand the air-pressure. The shaft was sunk to a depth of about 120 feet, but he (Mr. Latham) did not know whether this depth was measured from the water-level or from the top of the shaft, which was a few feet above the level of the sea. Englishmen, Irishmen, Scotchmen and Welshmen were all tried, and, if anything, the Irishman stood the pressure the best: the only condition that he made before he went into the shaft being that he should be supplied with unlimited quantities of beer when he came out. Workmen were then imported from the Continent, and it was found that Italians could stand a much

higher pressure than the representatives of any other nationality. In conversing with a medical gentleman on this subject recently, the latter pointed out that, perhaps, temperament explained the fitness of Italians for this class of work. The Italian was an easy-going, happy-go-lucky fellow, who took things very coolly, and seldom got excited.

Mr. Mottram had carefully examined the dangers which were to be encountered, and the methods and precautions which ought to be taken to reduce such risks; and he (Mr. Latham) felt sure that such knowledge would be of the greatest value in enabling mining engineers in the future to avoid many of the dangers arising from the use of compressed air for this class of work.

Mr. M. Walton Brown wrote that the following comparative costs of sinking through water-bearing strata had been taken from a paper by Mr. F. Lebreton.* Sinkings by the Triger system of compressed-air caissons:—A shaft was sunk at Havré colliery, through running sands and water-bearing chalk, 124 feet thick, in 48 months, at a cost of £888 19s. per foot; and another shaft, at la Louvière colliery, was sunk through quicksands, 42 feet thick, in two months, at a cost of £98 3s. per foot. Sinkings by the Poëtsch freezing system:—A shaft was sunk at the Archibald colliery, through quicksands, 131 feet thick, at a cost of £17 16s. per foot; another shaft, at the Emilia colliery, was sunk through sands, 140 feet thick, in eight months, at a cost of £25 16s. per foot; and another shaft, at Wasterhausen colliery, was sunk through sands, containing large boulders, 98 feet thick, at a cost of £30 per foot.

The following recommendations, applicable to the use of air-compressing plant, appeared to be especially suitable for adoption in connexion with the air-compressors used at caisson-sinkings:—

The air used for compressing purposes should be taken as pure as possible, care being taken, in selecting the site for the machinery, to avoid the vicinity of gas-works, burning heaps of waste-material, or any works, such as lime-kilns, producing stythe or smoke, or any other gases (inflammable or otherwise) which might be injurious or dangerous to life, if carried into the mine [caisson]. The use of illuminating-gas in the engine-house should be avoided, as a careless workman might leave a tap open, and the escaping gas might be drawn into the compressing cylinders. It would also be desirable to keep the machinery at some distance from the screens, so as to avoid the drawing of the fine coal-dust into the cylinders

* *Annales des Mines*, series 8, vol. viii., page 111; and *Trans. N. E. Inst.*, vol. xxxv., abs. page 33.

and delivery-pipes. Attention should be directed to the necessity of a constant and sufficient supply of water to the jackets of the air-cylinders, so as to prevent the danger of spontaneous combustion of deposits formed in the pipes or vessels. The danger of using mineral-oils of a low flashing-point, for lubricating air-compressing cylinders, is sufficiently obvious.*

The great essential in caisson-sinking appeared to be the supply of pure air, at a low temperature. The purity of the air in the caisson should be tested by a mouse or a canary. In the sinking of the Maria colliery, near Aix-la-Chapelle, through a quicksand, 121 feet thick, the air had a maximum pressure of 47 pounds or 3·2 atmospheres. The air in the caisson had a temperature of 52° to 56° Fahr. The work was completed in 228 days, and the men, working in the compressed air, experienced no ill effects. The men worked shifts of 8 hours, in three portions, with intervals of rest of ½ hour, during which they came to bank.†

The further discussion was adjourned.

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* "Report of the Committee appointed to enquire into the Explosion of an Air-receiver at Ryhope Colliery," by Mr. M. Walton Brown, *Trans. N. E. Inst.*, 1888, vol. xxxvii., page 204.

† *Zeitschrift für das Berg-, Hütten- und Salinen-wesen im Preussischen Staate*, 1885, vol. xxxiii., page 221; and *Trans. N. E. Inst.*, 1887, vol. xxxvi., abs. page 35.

MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD AT THE HARVEY INSTITUTE, BARNSLEY, NOVEMBER 8TH, 1905.

MR. T. W. H. MITCHELL, PRESIDENT, IN THE CHAIR.

The minutes of the previous General Meeting were read and confirmed.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. WILLIAM HENRY FUDGE, Under Manager, Hornes Terrace, Durkar, near Wakefield.

Mr. JOHN WILLIAM GARDNER, Mechanical Engineer, Elmfield, Outwood, Wakefield.

Mr. SAM HOPKINSON, Under Manager, 17, Ivanhoe Road, Conisborough.

Mr. FREDERICK ANTHONY STEART, Geological Survey Department, P.O. Box 978, Pretoria, Transvaal.

ASSOCIATE MEMBER—

Mr. GEORGE STEEPLES, 13, Joannah Street, Sunderland.

STUDENTS—

Mr. HAROLD CHARLES FIRTH JEFFCOCK, Mining Student, Birley Collieries, Sheffield.

Mr. SAM SWIFT, Mining Student, Lepton Colliery, near Huddersfield.

Mr. JOHN WILFRID TALBOT, Mining Student, Field Head, Batley, Yorkshire.

The PRESIDENT (Mr. T. W. H. Mitchell) read the following "Further Notes on Capels for Winding-ropes":—

FURTHER NOTES ON CAPELS FOR WINDING-ROPES.

By T. W. H. MITCHELL.

The writer has caused further tests to be made with different capels, in addition to those already reported on in his former note,* and the details of the results are given in Table II.

(1) This capel, supplied by the makers of the rope, was made on the principle of two wedges tightening against the rope as soon as it comes under tension. This capel was successful in breaking the rope (Fig. 1, Plate VIII.) at a load of 64·5 tons. The capel was attached to the rope by the makers, and the rope was tested in the same state as it was received from them. Attention is called to the note in Table II. shewing the extent to which the wedges were drawn out of the capel. This rope was stated to have a breaking-strain of 90 tons.

(2) The writer had a portion of the same rope tested for its breaking-strain only, using a capel which is ordinarily employed by the engineers when testing ropes.

(3) This test was made on a box-capel supplied to the writer. The rope (Fig. 1, Plate VIII.) was a piece cut from the same length as that used in Nos. 1 and 2 experiments.

(4) This test was made on an ordinary capel, 3 feet 6 inches long, described in the writer's former note,† and illustrated in Plate VIII. The only difference being that the rope was pulled right through, bound with soft No. 13 gauge copper-wire for a length of 21½ inches, and then opened out and cleaned for a length of 16 inches (Fig. 2) at the end, without turning the wires back. When this was done, two iron wedge-shaped pieces (Figs. 5 and 6) were inserted at the sides or joints of the capel (Fig. 3) and the collars driven home. White-metal, consisting of 60 per cent. of lead, 30 per cent. of tin, 9 per cent. of antimony and 1 per cent. of bismuth, as described by Mr. John Gerrard‡, was then

* Table I. contains the details of the experiments referred to in the writer's "Notes on Capels for Winding-ropes," *Trans. Inst. M. E.*, 1905, vol. xxix., page 173.

† *Ibid.*, page 174. ‡ *Ibid.*, page 178.

TABLE I.—RECORDING TESTS OF CAPELS.*

No. of Test.	Description of Capel.	Details of Ropes.						Stress in Tons.											Maximum Stress.	Total Elongation.
		Circumference	Layers or Strands.			Total Number of Wires.	Hemp Core.	1.	5.	10.	15.	20.	25.	30.	35.	40.	50.	60.		
			No. of Wires in Layers.	No. of Strands.	No. of Round Wires.			Elongation of the Rope on the tested Length.												
1	Locked-coil rope, 50 inches long, with a capel-attachment at one end.	Ins. 4·00	33 27 20 11 6 1	..	..	98	..	Ins. .. zero	Ins. zero zero	Ins. 0·02 Move zero	Ins. 0·06 ment 0·07	Ins. 0·07 of the 0·23	Ins. 0·10 rope 0·50	Ins. in the .	Ins. capel. ..	Ins.	Ins.	Ins.	Tons. 29·30	Ins. 0·13
2	Locked-coil rope, 50 inches long, with a capel attachment at one end.	4·00	33 27 20 11 6 1	..		98	..	.. zero	zero zero	0·04 Move zero	0·04 ment 0·40	0·04 of the 0·75	0·07 rope 1·50	0·10 in the 1·85	0·11 capel. 3·30	0·14 4·25	. .	.. ..	46·48	0·19
[illegible]	A length of 25 inches of the locked-coil rope used in No. 2 test.	4·00	33 27 20 11 6 1		..	98		..	zero	0·04	.	0·04	..	0·10	..	0·14	0·22	0·35	67·25	[illegible]
3	Ordinary rope, 50 inches long, with a capel-attachment at one end.	4·05	..	6	8 7	90	main	zero zero	0·06 zero	0·11 Move 0·04	0·15 ment 0·05	0·20 of the 0·06	0·28 rope 0·06	0·32 in the 0·35	0·42 capel 3·80	..	..	..	42·40	0·78
4	Ordinary rope, 50 inches long, with a capel-attachment at one end.	3·75	..	6	8 7	90	main	zero zero	0·05 zero	0·11 Move zero	0·18 ment 0·11	0·23 of the 0·20	0·36 rope 0·45	0·70 in the 7·90	.. capel	0·91 11·90	..	.. ..	42·06	..
4A	tested to de- d out of the capel in No. 4 test.	3·75	..	6	8 7	90	main	zero	0·05	0·11	0·18	0·23	0·70	0·91	..	0·91	1·12	..	46·23	1·18

with a load of ... the capel, and finally pulled through.
of 46·48 tons, ... , and finally pulled through.
ere broken to... Several of the wires were broken

ore wires broke. With a load of 32·1 tons, the rope pulled rapidly out of the capel,
apel. The wires were broken at different places along the length of the rope. The

e broke with a load of 24·70 tons. The rope pulled rapidly out of the capel with
fracture was found in the capel after the test was finished.

Vinding-ropes, *Trans. Inst. M.E.*, 1905, vol. xxix., page 173.

TABLE II.—RECORDING TESTS OF CAPELS.

Description of Capel.	Locked-coil Ropes. Circumference.	Weight per Fathom.	Rings or Layers. No. of Wires.	Shape of Section of Wires.	Total Number of Wires.	Stress in Tons. 1.	5.	10.	20.	25.	[redacted]	40.	50.	60.	Maximum Stress.	Total Elongation.
						Elongation of the Rope on the tested Length of 50 Inches.										
	Inches.	Pounds				Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Tons.	Inches.
.ocked-coil rope, with a capel-attachment at one end.	3·85	21·46	33	recess	93	zero	0·00	0·02	0·18	0·20	0·23	0·40	0·68	1·38	64·50	2·32
			26	wedge			Move	ment	of the	rope	from	the we	dges.			
			16	round		zero	0·00	0·00	0·01	0·05	0·06	0·11	0·14	...		
			11	,,			Pull	ing up	of the	wedg	es on	the sh	eath			
			6	,,		zero	0·00	0·00	0·00	0·00	0·10	0·20	0·47	..		
			1	,,												
nother length of locked-coil rope, cut from the same rope as that used in No. 1 test.	3·85	21·46	33	recess	93	zero	0·05	0·10	0·20		0·31	0·49	0·72	1·32	65·27	2·30
			26	wedge												
			16	round												
			11	,,												
			6	,,												
			1	,,												
.ocked-coil rope, with a box-capel fixed at one end.	3·85	21·46	33	recess	93	zero	0·08	0·12	0·20		0·31	0·48	0·68	1·26	65·38	2·32
			26	wedge			Mov	ement	of the	rope	in the	capel.				
			16	round		zero	0·02	0·07	0·13		0·18	0·23	0·25	0·28		
			11	,,												
			6	,,												
			1	,,												
.ocked-coil rope, with a capel-attachment at one end.	3·85	21·46	33	recess	93	zero	0·03	0·09	0·20		0·30	0·43	0·63	1·06	64·92	1·98
			26	wedge			Mov	ement	of the	rope	in the	capel.				
			16	round		zero	0·02	0·04	0·07		0·14	0·15	0·23	0·35		
			11	,,												
			6	,,												
			1	,,												

of

and, with a load of 64·5 tons the rope broke as a whole at a position corresponding to the front edges of the wedge. The total length of travel of the wedges during the test was 2 inches.

The ratio of the holding-power of the capel to the breaking-load of the rope was 98·8 per cent.

The total movement of the rope in the capel was 0·35 inch

poured in, forming a length of 25 inches. When cooled down properly, the wedge-shaped pieces of iron were taken out and the collars were driven tightly home on the white-metal. Figs. 7 and 8 shew the rope-end with the capel removed. This arrangement was carried out by their engineer, Mr. S. Brittain, and tested with the results shewn in Table II.

In the writer's opinion, the success of this form of capel shews that it does not matter particularly what is the shape of the capel, so long as no wires are turned back, and the white metal is run in carefully. The writer was somewhat astonished to find that a rope, described as having a breaking-strain of 90 tons, should break in two or three cases with a load of about 65 tons, and the experience of other members on this point would be useful. The explanation given is that the cutting of the rope into short lengths imperceptibly disintegrates the wires, so that they do not all take the same stress.

The locked-coil rope (Fig. 1, Plate VIII.) used in the tests was 3·85 inches in circumference, and weighed 21·46 pounds per fathom. There were 33 recess-shaped wires in the outer ring of the rope, 26 wedge-shaped wires in the second ring, 16 round wires in the third ring, 11 round wires in the fourth ring, 6 round wires in the fifth ring, and the central core was a round wire.

The method of calculating the strength of a rope seems to be as follows:—Locked-coil rope, No. 2,254 (Fig. 1, Plate VIII.), a sample of which was sent to the Sheffield Testing Works, made of improved plough-steel, contained 6 round wires in the fifth ring, 11 round wires in the fourth ring and 16 round wires in the third ring, and 33 round wires at 2,270 pounds equals 74,910 pounds; 26 wedge-shaped wires at 2,115 pounds equals 54,990 pounds; and 33 recess-shaped wires at 2,164 pounds equals 71,412 pounds; making a total breaking-strain of 201,312 pounds or 89·87 tons, or, say, 89¾ tons.

Mr. W. Walker (H.M. Inspector of Mines) said that he had taken the opportunity of seeing some of the tests made at Sheffield, and he could not understand why the ropes broke in all of them at about 65 tons. The results of the experiments seemed to be very even, and to give a breaking-strain practically

of 72 per cent., yet in other experiments, with the same description of capel and rope, from 90 to 100 per cent. of the theoretical breaking-strain of the rope was obtained. Messrs. Glaholm and Robson, of Sunderland, had sent him the results of a test of an ordinary stranded rope for the Pekin syndicate. The breaking-strain was guaranteed at 84 tons, and the rope broke at 87·40 tons. The capel was formed in the following manner: (1) Bind the end of the rope securely, and after measuring the length of the chamber of the socket to be fixed, bind the rope again at that distance so as to prevent the strands from unlaying when the wires are opened out. (2) Pass the rings in their proper order on the rope, push the rope through the chamber of the socket; and then drive the rings back into the socket. Fill the apertures at the sides and bottom with clay, so as to keep the metal from running out when poured in. (3) Open out the strands to the second binding, thoroughly clean the wires and place the socket in a vertical position, then draw the rope level with the top of the chamber, and pour in the molten spelter. (4) Allow it to cool, caulk the rings in their position, remove the temporary bindings and dress, with a file, the spelter at the top of the chamber of the socket. That method was practically the same as that used by Mr. Brittain, of Mitchell Main colliery. The metal used for filling the socket was composed of a good quality of spelter, with the addition of 10 per cent. of tin. He thought that this information shewed that such capels did give a maximum breaking-strain. At a colliery, he recently raised the question with the engineer, who said that he preferred the old-fashioned capels, because they gave some notice of when they were about to draw, and the others did not. Personally, he could not agree with that view, holding that the bigger margin of breaking-strain must give a greater degree of safety.

Mr. M. H. Habershon said that a few years ago he felt some doubt as to whether the old-fashioned capel was satisfactory and an improved form had been adopted. After reading Mr. Mitchell's paper, it was thought desirable to make a test, and, accordingly, a length was cut from a rope in work, and it was tested at Sheffield. The rope, 4¾ inches in diameter, was made of special plough-steel, with six strands, ½ inch in diameter, and a main hemp core. The rope broke under a stress of 83·3 tons, but the capel was not injured: a slight movement was noticed when

the strain first came on, but it did not go any further. A second piece of the same rope broke at 81·9 tons, so that the full percentage was realized. This capel was made in the old-fashioned form, but none of the wires were turned back. The method of capelling was to open out the strands for a length of 3 or 4 feet, and then replace them on the top of an iron plug 3 feet long, which tapered from a diameter of $\frac{5}{8}$ inch to $1\frac{9}{16}$ inches, the original lay of the strands being maintained. After replacing the various strands on this plug, the spaces between them were filled with short lengths of the strands, which were tapered to a point so as to fill in the spaces left, and annealed. This solid end, 3 feet long, was then wrapped with steel-wire and inserted in a capel of the ordinary form, bound together by six iron hoops, 1 inch thick and of varying widths, driven on cold.

Mr. H. Ingold (Sheffield) said that he saw the tests made on Nos. 3 and 4 samples. In the third test, about twelve of the outer wires and a few of the inner ones broke first; and, in the fourth test, only four outer wires broke first, and about the same number of the inner wires. The tests of the four samples only gave 72 per cent. of the aggregate strain of the wires. Testing-machine results with locked-coil ropes could not be taken as accurate, as it was difficult to fasten the ends, without disturbing the twist of the wires, and practically impossible to prevent the slackening of some of the wires. Consequently, the wires could not take their proper share of the load. In the two instances quoted, so small a proportion of the wires broke together, that there could be little doubt that the rope, when in use, would stand a much higher tensile breaking-strain than that obtained on the testing-machine.

Mr. Brittain's adaptation of an ordinary winding-rope capel (Figs. 3 and 4, Plate VIII.) for use with white-metal in the fourth test, was ingenious: he converted it into a solid capel by putting in liners, and, after casting, removed them, enabling the hoops to be driven up. He noticed that the capel was 42 inches long, and, as that was probably his first attempt, the test was highly satisfactory. The capel, about 24 inches long, used in the third test, was made from a mild-steel forging, machined all over in order to make sure that there was no flaw in the material.

He proposed, shortly, to carry out a series of experiments with locked-coil ropes, on a 100 tons wire-rope testing-machine. He hoped that the experiments would enable him to find the percentage of loss of the aggregate strength of the wires due to spinning, and, perhaps, a method of cutting off and preparing the ends of the samples, by which a larger proportion of the wires would carry the load.

Tensile tests of ordinary wire-ropes, made of round wires, twisted into round strands and closed into round ropes, were much more regular and reliable. The tensile breaking-strain of the usual sections of winding-ropes might be taken at 80 to 90 per cent. of the aggregate strain of the wires; but that percentage decreased in very large ropes, probably owing to the untwisting of the short sample tested, owing to the springing of the wires. He agreed, when using white-metal capels, that the wires should not be turned backward, as the cleaning of the wires could be better done; they need not be handled after cleaning; and the white-metal could more easily run round each individual wire. He was so assured of the efficiency of this method of fastening, that, in 1901, he had 280 samples of rope, with 560 ends, tested in that way for the British Admiralty, and not one of them drew out before the rope was broken. These tests gave 85 to 90 per cent. of the aggregate strain of the wires.

FIG. 10.—OPEN SHACKLE AND CAPEL FOR HAULING-ROPES.
SCALE, 4 INCHES TO 1 INCH.

A capel of the open-shackle type (Fig. 10), principally used for quarry-crane ropes, was employed on account of convenience in testing. It was fastened to a winding-rope 1¾ inches in diameter. It was 11⅜ inches long, the barrel was only 5⅜ inches long, and none of the wires were turned backward. The result of 53·35 tons was remarkably and

unusually good, being 93 per cent. of the aggregate strain of the wires: the estimated breaking-strain being 51·62 tons. The casting proved to be quite sound, when sawn through.

Another capel of the closed weldless type (Fig. 11) was largely used for hauling-ropes (⅝ inch in diameter): for underground work, the wires would be turned backward, and a small iron peg driven in; and, for surface work, white-metal could be used. The size of this capel (6¼ inches long and barrel 2¼ inches long) would not, of course, allow of its use on winding-ropes, owing to its diminutive appearance, but it shewed that even a small capel could be stronger than the rope.

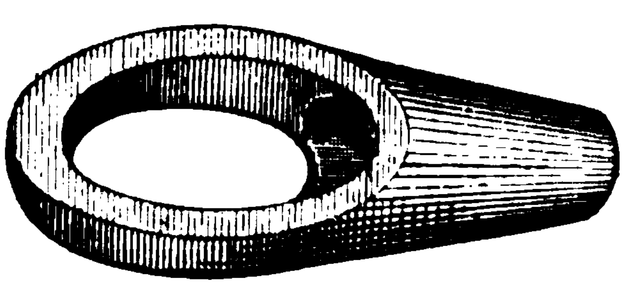

FIG. 11.—CLOSED SHACKLE AND CAPEL FOR HAULING-ROPES. SCALE, 4 INCHES TO 1 INCH.

White-metal capels were the strongest fastenings known, but great care was necessary in putting them on, the points to be watched being: the use of a proper alloy, the temperature at which it was melted and used, the cleaning of the wires, and the shape of the capel.

Mr. J. R. R. WILSON (H.M. Inspector of Mines) pointed out that there were hundreds of quarries in the Yorkshire mines-inspection district, and he had made special enquiries on the subject of rope-breakages. Almost universally, a small box-capel was used, the attachment being made by running in white-metal as had been described, and it was very rarely indeed that the capel was drawn. Sometimes, a stone which had to be pulled out of the quarry, was not properly dislodged from its bed, and when the crane-rope was applied, it was subjected to a very severe strain. Ropes had broken under such conditions, the drum-axles had been bent, even the drums had been broken, but very rarely was the capel drawn. The box-form of capel had the further advantage that it obviated the use of rings, such as were commonly adopted, especially upon large rope-attachments. He had known instances where rings had become loose and stripped, resulting in serious personal injury and destruction of property.

The tests recorded in Mr. Mitchell's paper, and other instances of weakness shown in locked-coil ropes, raised the question, which he thought ought to be considered, of the advisability of using these ropes for ordinary winding, especially in

upcast-shafts. It would be of interest and value to the members if someone, who was thoroughly conversant with the manufacture of such ropes, would give his opinion.

Mr. H. B. NASH thought that the results of the tests made on locked-coil ropes were an eye-opener to many engineers, who were responsible for the working of such ropes. It was a serious matter to be told, after running a rope for four months with a guaranteed breaking-strain of 90 tons, that they must consider that strain to be reduced to 65 tons, because, owing to its being recapped, such a rearrangement of the internal wires of the rope had taken place, as to bring about this result. In his opinion, the question resolved itself into whether it was not more advantageous to use a rope of ordinary lay, upon which a reasonable amount of reliance could be placed, than to use a locked-coil rope, which, according to the tests made, broke in every instance at about two-thirds of its guaranteed breaking-strain. If the makers of locked-coil ropes could give some assurance that the breaking-strains were reliable, instead of stating that, after a short life or in the case of recapping, they could not be properly tested owing to the rearrangement of the internal wires, it would create a much greater feeling of security in the minds of the users. The frequent recapping of winding and other ropes was for the sole purpose of obtaining increased safety, and, in the case of locked-coil ropes, apparently, it had just the reverse effect and defeated its own object.

Mr. ISAAC HODGES pointed out that the rope-makers' guaranteed breaking-strain for winding-ropes of ordinary lay was usually 15 per cent. less than the computed breaking-strain ascertained by multiplying the breaking-strain of one wire by the number of wires in the rope. This allowance was made, as it was obvious that all the wires could not take an equal strain at one time. If this deduction was made from the 89¾ tons computed breaking-strain of the locked-coil rope, described by Mr. Mitchell, it would bring the guaranteed real breaking-strain to 76½ tons, which was fairly near the 65 tons at which the rope actually broke under the several tests.

The PRESIDENT (Mr. T. W. H. Mitchell) did not think that the deduction was made.

DISCUSSION OF MR. A. HASSAM'S PAPER ON "THE TAXATION OF COLLIERIES."*

The PRESIDENT (Mr. T. W. H. Mitchell) said that municipal debts had increased in twenty-eight years nearly 300 per cent.; the rateable value had increased about 55 per cent.; the poundage had increased from 3s. 3d. to 5s. 7d. or nearly 70 per cent.; whilst the population had increased by only 39 per cent.† Attention was directed to the method of assessing the income-tax, the anomaly occurring in the case of a colliery, which, on a yearly basis should pay about £1,333, only paid £416 on the five-years' basis; whereas, in bad times, when only £95 was due, it had to pay £678.‡ Mr. Hassam did not refer to the fact that to get a reduction of the tax, a three-years' basis only was allowed. He (Mr. Mitchell) did not think that Mr. Hassam had given sufficient attention to the allowance for depreciation. In his experience, the only allowance granted was 3 per cent., and it did not in any way allow for the proprietors' capital which was being worn away every year. Mr. Hassam directed special attention to the fact that Assessment Committees in all the unions were virtually a law unto themselves: thus, in Glamorganshire, the gross valuation averaged 8·44d. per ton; and in Derbyshire, it was only 2·09d. per ton. Unfairness existed in each union, where the basis was taken on the tonnage or the acreage, because a colliery that had great difficulties to overcome, say, as to water and faults, was valued on the same basis as one free of all difficulty. Perhaps some member could speak on the typical case given by Sir Edward Boyle, where he proposed a sinking-fund at 2½ per cent. to repay the cost of the plant in 30 years; and a sinking-fund at 2½ per cent. to replace the shafts in 60 years. He asked whether anyone had been able to obtain such allowances.

The discussion was closed.

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* *Trans. Inst. M. E.*, 1905, vol. xxix., page 90; and 1905, vol. xxx., page 24.

† *Ibid.*, vol. xxix., page 91.

‡ *Ibid.*, vol. xxix., page 96.

DISCUSSION OF MESSRS. G. BLAKE WALKER AND L. T. O'SHEA'S PAPER ON "THE UTILIZATION OF SURPLUS-GASES FROM BYE-PRODUCT COKE-OVENS,"* AND OF MR. A. J. TONGE'S PAPER ON "A COLLIERY-PLANT: ITS ECONOMY AND WASTE."†

Mr. G. Blake Walker said that, since the paper was read, he had visited Germany, where this question was being taken up on a large scale, and several important plants had been erected. He had obtained the following particulars of the working of two important installations:—

Gas-power Plant at the Constantin der Grosse Colliery.—The gas-power plant at the No. 2 pit of the Constantin der Grosse colliery consists of a twin-cylinder Deutz gas-engine of 600 horsepower, with a flywheel weighing 5 tons, and a generator; and a tandem Nürnberg gas-engine, of 1,200 horsepower, with a flywheel armature arranged for 3,500 volts and capable of working in parallel. The flywheel and dynamo weigh 45 tons.

The gases supplied to these engines comprized:—(1) Producer-gas, obtained from two producers and used in the Deutz gas-engine; and (2) coke-oven gases obtained from 60 Otto-Hoffmann ovens of 7·5 tons capacity. Forty ovens are discharged every 24 hours, the yield of gas is 3,850,000 cubic feet, 2,800,000 to 2,975,000 cubic feet are employed in heating the flues, and 875,000 to 1,050,000 cubic feet are available for boiler-firing and in gas-engines. The gases, after passing through the bye-product plant, are purified in three dry purifiers arranged with five grids, on which wood-shavings and oxide of iron are used. The purified gas is delivered from a gas-holder at a pressure of 5½ inches, and a temperature of 77° Fahr. The average composition of the gases is as follows:—Nitrogen, 16·05 per cent.; carbon dioxide, 0·59 per cent.; oxygen, 0·76 per cent.; heavy hydrocarbons, 0·76 per cent.; marsh-gas, 20·47 per cent.; hydrogen, 55·98 per cent.; and carbon monoxide, 5·13 per cent.: there being 82·34 per cent. of heat-producing gases. The heating value of the gas, estimated from three different tests, was 4,226 calories per cubic metre or about 460 British thermal units per cubic foot.

* *Trans. Inst. M. E.*, 1905, vol. xxix., page 187.

† *Ibid.*, 1905, vol. xxix., page 153.

The gas-consumption of the Nürnberg engine of 1,200 horsepower is 700,000 cubic feet per 24 hours or 24·3 cubic feet per horsepower-hour; and it is hoped that it may be reduced. The water required for cooling the cylinders is about 2,920 cubic feet per hour or about 2·4 cubic feet per horsepower-hour, and about 7,000 cubic feet of water are lost per day. The water enters the cooling-jacket at a temperature of 77° to 86° Fahr., leaves at a temperature of 113° to 122° Fahr., and is afterwards cooled by the Schwarz chimney-cooling system. The oil-consumption of the Nürnberg engine is 8·8 gallons per day. The starting of the Nürnberg engine is effected by the use of air at a pressure of 22 atmospheres.

The cost of the plant was as follows:—(1) Deutz gas-engine of 600 horsepower: foundations, £800; engines, pipe-connections, etc., £5,500; a total of £6,300. (2) Nürnberg gas-engine of 1,200 horsepower: foundation, £1,200; engine, pipe-connections, etc., £7,500; a total of £8,700. (3) Buildings, etc.: buildings, £4,500; cooling plant, £1,250; gas-purifying plant, £1,500; a total of £7,250. (4) The total cost was £22,250, equal to £12 3s. 6d. per horsepower; and the cost, exclusive of buildings, but including cooling and purifying plant, was £17,750, equal to £9 8s. 6d. per horsepower.

The working expenses for the Nürnberg engine of 1,200 horsepower are £1,100 per annum, exclusive of the gas, which is estimated to cost 0·125d. per horsepower-hour.

Gas-power Plant at the Consolidation Colliery.—At the Consolidation colliery, the gas-engine plant comprizes two tandem double-acting four-cycle Nürnberg gas-engines, each of 680 horsepower, and one single-cylinder Otto gas-engine of 160 horsepower; a total of 1,520 horsepower. The plant is driving two alternators at a pressure of 5,000 volts, with a frequency of 100 cycles per second. The capacity under an inductive load is 630 kilowatts, at 125 revolutions per minute.

The plant driven by the electric current, thus generated, is as follows:—(1) Pumping: Two Sulzer high-pressure centrifugal pumps, having a capacity of 656 gallons per minute, under a head of 2,109 feet. (2) Air-compressors: One horizontal two-stage compound air-compressor with piston-valves on the Köster system, having a capacity of 140,000 cubic feet of free air per minute at a speed of 121 revolutions per minute: the air being

compressed to 6 atmospheres. (3) Coke-pushing machine. (4) Lighting of the No. 6 seam loading-station and the pumping-installations. (5) It is intended eventually to use electricity to drive the machinery in the workshops and the coal-washer. The lighting of the surface-plant is also effected by means of a gas-engine driving a shunt-wound direct-current dynamo of 110 volts, and a capacity of 116 kilowatts, when running at 150 revolutions per minute.

The available gas, obtained from Otto-Hilgenstock ovens, is about 795,000 cubic feet in 24 hours or 22 cubic feet per horsepower-hour, and equal to 23·7 per cent. of the total gas obtained from the coal. The gas is purified before passing to the engines, and its heating value is 4,000 calories per cubic metre or 450 British thermal units per cubic foot.

The water required to cool the cylinders is 1·33 cubic feet per horsepower-hour, or 2,000 cubic feet per hour for 1,520 horsepower. The water is cooled and used again.

The cost of the plant was as follows:—(1) Engines: two gas-engines, each of 680 horsepower, £8,450; one gas-engine of 160 horsepower, £1,880; travelling-crane, £413; pipe-connections, etc., £1,522; a total of £12,265. (2) Electric plant: two alternators and one direct-current dynamo, £3,607; air-compressor for starting the motors, £187; switchboard, cables and transformers, £1,087; lighting of central station, £150; a total of £5,031. (3) Accessory plant: purifying-plant and buildings, £1,625; cooling-plant, £927; gas-regulator, £150; a total of £2,702. The total cost of £19,998 is equivalent to £13 15s. per horsepower.

The working expenses are only estimated, as the plant has only been working for about three months: they are per day as follows:—Cleaning engines, £2 2s. 9d.; oil, £1 5s.; purifying the gas, 5d.; a total of £3 8s. 2d. or approximately £1,240 per annum. Only a few small stoppages have occurred through the fusion of sparking-plugs, since the plant was started.

Mr. H. B. Nash wrote that, at Messrs. Bell Brothers' Port Clarence works, there was a battery of sixty Huessener coke-ovens and six Lancashire boilers, each 30 feet long and 8 feet in diameter, attached to the waste-heat flue. Five boilers were in use at one time, and the steam from them was used in driving

an electrical installation of 1,000 kilowatts. This power was derived from the waste-heat alone, no gas being used, and as Messrs. Bell Brothers have, at present, all the power that they require, the surplus-gas is burnt away in large torches.

Dr. Roelofsen, of the Coal-distillation Company, who is in charge of this plant, made the following tests during the first week in September, 1905, to determine the actual work being done by the waste-heat, and also what further work could be done in steam-raising with the surplus-gases. The results of the tests are as follows:—(1) 297 tons 10 cwts. of dry coal, charged with 10 per cent. of moisture, were carbonized per 24 hours or 27,800 pounds of coal per hour. (2) The water evaporated by the waste-heat only was 23,750 pounds per hour or 0·855 pound of water evaporated per pound of coal carbonized: the boilers working at a pressure of 120 pounds per square inch. (3) The water evaporated by the surplus-gases was 14,500 pounds per hour, or a further evaporation of 0·521 pound of water per pound of coal carbonized: the boilers working at a pressure of 120 pounds per square inch. (4) The total evaporation was, therefore, 1·376 pounds of water per pound of coal carbonized, at a boiler-pressure of 120 pounds per square inch. The feed-water was heated by the exhaust-steam from the dynamo-engines, and was fed into the boilers at a temperature of 170° Fahr.

Mr. H. Rhodes, referring to Mr. Tonge's paper on "A Colliery-plant: its Economy and Waste," said they wanted to obtain now the actual cost of coal used for colliery consumption, and the percentage of coal consumed to coal used afforded no real information. The boiler-fires might burn 5 per cent. of unsaleable slack, which might cost less than 1 per cent. of smudge, suitable for coking and the recovery of the bye-products.

THE SOUTH STAFFORDSHIRE AND WARWICKSHIRE INSTITUTE OF MINING ENGINEERS.

ANNUAL GENERAL MEETING,

HELD AT THE UNIVERSITY, BIRMINGHAM, OCTOBER 16TH, 1905.

PROF. R. A. S. REDMAYNE IN THE CHAIR.

The minutes of the last General Meeting and of Council Meetings were read and confirmed.

The following gentlemen were elected:—

MEMBERS—

Mr. H. C. READ, Mining Engineer, The University, Birmingham.
Mr. A. L. RONALDSON, Mining Engineer, London.

ASSOCIATE—

Mr. ELIJAH ROWLEY, Heath Hayes, Cannock.

ELECTION OF OFFICERS, 1905-1906.

The SCRUTINEERS reported that the following gentlemen had been elected:—

PRESIDENT: Mr. W. N. ATKINSON.
VICE-PRESIDENT: Mr. F. A. GRAYSTON.
NEW MEMBERS OF COUNCIL:

Mr. F. BROWN. | Mr. J. H. W. LAVERICK.
Mr. W. HILL. | Mr. D. E. PARRY.
Mr. F. C. SWALLOW.

The Annual Report of the Council and the Treasurer's Accounts were read as follows:—

ANNUAL REPORT OF THE COUNCIL, 1904-1905.

The members are to be congratulated on the conclusion of a successful year, for, although the membership is smaller, the receipts are larger than last year by £25 6s., and the bank-balance has been increased by £8 16s. 1d. The membership is 174 as against 192 last year, the difference having been caused by the death of 2 members, Messrs. F. Scott and Thomas Longstaff; 2 resignations; 24 struck off by the Council in accordance with the rules for non-payment of subscriptions; and 10 members have been elected. The arrears of subscriptions are still large, and it cannot be too strongly urged upon members that the good work of the Institute cannot be efficiently carried on unless all subscriptions are paid when due. The amount of subscriptions now in arrear is £200 3s., and of course a large amount has had to be written off on account of those expunged from the register.

The name of the Institute was altered at the General Meeting held on June 5th, 1905. It was thought that "East Worcestershire" had lost its previous importance as a coal-mining centre, whereas "Warwickshire" had assumed a very prominent position among the coal-fields of the Midlands. The undoubted correlation of the Warwickshire coal-field with that of South Staffordshire, and the fact that this Institute always considered Warwickshire within its sphere and almost all the leading mining engineers in that county were members, made it desirable that some recognition of its increasing importance should be made. In addition, the Institute's headquarters are in Birmingham, the chief town of Warwickshire.

There have been five General Meetings, six Council Meetings and one joint-excursion, in the summer, with the North Staffordshire Institute of Mining and Mechanical Engineers, when the works of the Mond Gas (Power and Heating) Corporation at Dudley Port and the Birmingham University buildings were visited.

An interesting address was delivered by the President, Prof. R. A. S. Redmayne, and other papers contributed during the year were:—

Dr. THE TREASURER IN ACCOUNT WITH THE SOUTH STAFFORDSHIRE AND WARWICKSHIRE INSTITUTE OF MINING ENGINEERS, FOR THE YEAR ENDING JULY 31ST, 1905. **Cr.**

	£	s.	d.		£	s.	d.
To balance in bank	195	18	0	By The Institution of Mining Engineers	94	8	3
,, subscriptions received	185	10	6	,, rent of room, etc.	20	0	0
,, bank-interest	3	3	3	,, secretary's and reporter's salaries	50	0	0
,, sales of *Transactions*, etc.	3	18	6	,, printing, stationery, auditors, etc.	9	17	0
				,, postages, telegrams, etc.	6	10	11
				,, Prussian Reports on Falls of Stone and Coal	3	0	0
				,, balance in bank	204	14	1
	£388	10	3		£388	10	3

BALANCE-SHEET, 1905.

Liabilities.	£	s.	d.	**Assets.**	£	s.	d.
The Institution of Mining Engineers	36	18	9	By subscriptions due	200	3	0
To balance	367	18	4	,, balance in bank	204	14	1
	£404	17	1		£404	17	1

Examined and found correct,

DANIEL ROGERS.
WILLIAM H. WHITEHOUSE.

October 16*th*, 1905.

This balance is exclusive of considerably more than £100 worth of property, for which no credit is taken.

"Tapping and Running-off a Head of Water from a Shaft." By Mr. J. Fox.
"Problems of Working Thick Coal in Deep Mines." By Mr. L. Holland.
"Pneumatic Coal-boring Machines and Tools." By Mr. W. Lynch.

Prof. Redmayne's address, in conjunction with Mr. Holland's paper, elicited a long and valuable discussion.

During the year, the Secretary was instructed to communicate with the other Federated Institutes, with the object of a Committee being formed, composed of representatives from all the Institutes, with a view to approaching the South Wales Institute of Engineers and the Institution of Mining and Metallurgy, urging them to become federated with the Institution of Mining Engineers. Representatives were appointed by all of the Institutes, with the exception of the North of England Institute of Mining and Mechanical Engineers and the Mining Institute of Scotland, who declined; and as these Institutes embrace in membership something like two-thirds of The Institution of Mining Engineers, it was felt that little could be done without their support. However, your Secretary brought the matter forward at the meeting of the Council held in London, and it was left in the hands of a leading member to negotiate with the South Wales Institute of Engineers.

The Institution of Mining Engineers continues to flourish, and, as intimated last year, the Manchester Geological and Mining Society has become federated, leaving the South Wales Institute of Engineers the only purely coal-mining institute outside of the federation. The number of members of all grades is 3,034, and 77 papers have been contributed during the past year.

The thanks of the Institute are again due, and are hereby tendered, to the authorities of the Birmingham University for providing rooms for the use of the Institute.

The Annual Report of the Council, the Treasurer's Accounts and the Balance-sheet for the past year were adopted.

The PRESIDENT (Mr. W. N. Atkinson) delivered the following address:—

PRESIDENTIAL ADDRESS.

BY W. N. ATKINSON.

I have much pleasure in accepting the post of President of the South Staffordshire and Warwickshire Institute of Mining Engineers, and I thank you heartily for the honour which you have conferred in electing me.

The first subject on which I should like to say a few words is the present position of the Institute. The influence, activity and usefulness of corporate bodies are liable to fluctuate from a variety of causes, and I am afraid that the South Staffordshire and Warwickshire Institute of Mining Engineers is passing through a period of some depression. The attendance at the meetings is not so good as might be expected in so important a mining district as that which the Institute represents; and, on looking through the list of members, one notices the absence of the names of many gentlemen who should be supporters of this Institute. One of our immediate objects should be to increase the membership, and, in this direction, each individual member may assist by pointing out to his friends, who are eligible, but not yet members, the advantages of joining the Institute. An increased membership would naturally lead to a larger attendance at our meetings, and I would urge on all present members that it is a sort of moral duty to attend the meetings as often as possible.

The greatest attraction to a meeting is, of course, the reading of an interesting paper, or the discussion of some important or novel subject connected with mining or engineering or allied subjects. To be interesting and useful a paper need not be of a nature involving extensive research or prolonged investigations; such papers must necessarily be infrequent, but short, practical papers on subjects within the experience of members, should be forthcoming oftener than they are at present. A similar lack of papers is experienced by other Institutes.

I was conversing recently with Mr. W. E. Garforth, a past-president of the Midland Institute of Mining, Civil and Mechanical Engineers, and he suggested that members should select papers read before any of the Federated Institutes, and write a short criticism of or addendum to the paper, so as to introduce a discussion, and this I think is a useful suggestion which we might follow up with advantage.

The *Reports* of the Royal Commission on Coal-supplies might supply materials for many addresses, but I propose to refer only to certain figures relating to the South Staffordshire and East Worcestershire coal-field. According to the *Report* of Prof. C. Lapworth and Mr. A. Sopwith, the estimated net available quantity of coal remaining unworked in this coal-field, within the depth of 4,000 feet, is in round numbers, 1,415,000,000 tons, of which 874,000,000 tons is in the visible coal-field and 541,000,000 tons in proved extensions of the coal-field. It is not possible to estimate accurately what proportion the coal already gotten bears to the available coal remaining, but the most liberal estimate of the former quantity would leave a far larger amount remaining to be gotten, and including the probable further extensions of the proved coal-field, there is sufficient coal to remove any fear of a scarcity for many generations; but, at the same time, there is no prospect that coal will ever again be so cheap as it was in past years.

The question of the extension of the visible coal-field, both to the east and to the west, is of the highest importance to the district; and it appears to be a sound recommendation of the Royal Commission on Coal-supplies that there should be machinery for the preservation in a Government office of information obtained by boring, and (I would add) by sinking and driving underground headings in certain cases, adequate protection for private interests being also provided for. The Institute might do a good work by collecting sections of the strata all over the district, scores or hundreds of which are probably in the hands of members. Such a work has already been accomplished by the North of England Institute of Mining and Mechanical Engineers, which has published several volumes of sinking and boring records relating to the northern coal-field.

In considering the South Staffordshire coal-field, one's atten-

tion is naturally attracted to the Black Country section of the field, underlain by the famous Thick coal-seam. In their *Report*, above referred to, Messrs. Lapworth and Sopwith say of this portion:—

> In the southern district, however, the conditions are different: the great thickness of the principal seam, the Thick coal (reaching as much as 30 feet), its comparatively shallow depth, and the extended time during which it has been worked, have led to division and subdivision of the colliery-areas. Again, it has been found profitable, from time to time, to re-open workings for the purpose of winning some of the pillars: and this operation has frequently been repeated to the extent of a third and fourth working. These conditions have rendered the estimation of quantities a complicated matter, requiring research into many old mining plans dating as far back as the commencement of the last century. Again, out of 197 collieries, there were at the commencement of this enquiry 170 employing less than 100 men, with an average of 26 (including surface). There were 142 collieries with an average of only 17 men.

It is this portion of the coal-field, which is sometimes said to be "worked out"; but, as the estimated net available quantity of coal remaining unworked in this portion is, in the proved coal-field, 345,000,000 tons, and the present rate of output under 3,000,000 tons per annum, it is evident that the term "worked out" cannot be applied to the Black Country coal-field as a whole.

The easy access to, and great thickness of, the principal coal-seam appears to have led in the past to the working of it in an extravagant, wasteful and unscientific manner; and for this I apprehend that the "butty system" of working the pits is largely responsible. This system, in which the interests and influence of the charter-masters are greater than those of the mining engineers, if not also than those of the nominal owner, still unfortunately lingers in the Black Country, where many of the pits are worked pretty much as they were in the first half of the last century.

It is no doubt a difficult problem now to introduce improved methods and appliances in an ancient and much worked district, such as is the bulk of the Black Country; but, in some directions, I think that it is practicable to do so with advantage. Many of the mines should be fitted with small fans to ensure efficient ventilation in all states of the weather. The construction of better underground haulage-roads and a wider application of mechanical haulage would in many cases be highly beneficial.

The district is now provided with an electric power-station and a Mond gas-plant, and it does not appear unreasonable to suggest that advantage should be taken of these sources of power and heat, where they are available, for working the mines.

The treatment of the coal, after it reaches the surface, also appears to be worthy of consideration. In many cases, it is tipped direct out of the pit-tubs into canal-boats and sent away, as I understand, without the correct weight being known. This is no doubt a very simple and easy way of getting rid of the coal, but it is difficult to believe that it is the best way, in the interests of the colliery-owner.

Most of the Black Country mine-owners are to a large extent relieved of the necessity of unwatering their mines by the operations of the Mines-drainage Commissioners, and although the cost in many cases may be onerous, it is practically the only way of dealing with the water in such a district; without it much coal would have been inaccessible.

A Committee of the Institute was recently appointed to enquire into the methods of working the South Staffordshire Thick coal-seam. I hope that this Committee will soon be got to work, and the reference should, I think, be widened so as to embrace the thick seams of Warwickshire. It might be thought that this question should now be settled by long experience, but even an account of the circumstances rendering modifications of the ordinary system necessary, and whether successful or otherwise, would be useful; as also a record of unusual experiences concerning gob-fires, and other difficulties encountered in working such seams. Then again, if it were found practicable to introduce the system of water-flushed packing, that would entail profound modifications in the existing systems of working.

In conclusion, I am glad to allude to the advantages accruing to the South Staffordshire and Warwickshire coal-fields by their proximity to Birmingham University, and the schools of mining and metallurgy there, presided over by your late President, Prof. R. A. S. Redmayne, and Prof. Thomas Turner; and I would urge all the mining and metallurgical students in the district to take the fullest possible advantage of the technical and scientific training given at this University.

I again thank you for making me your President for the coming year, and with the assistance and co-operation of the Council and members, and of our worthy Secretary, I assure you that I will do my best to carry on successfully the work of the Institute.

Mr. Henry Johnson proposed a hearty vote of thanks to the President for his address.

Mr. W. F. Clark seconded the resolution, which was carried unanimously.

The President (Mr. W. N. Atkinson) proposed a hearty vote of thanks to the Retiring-President (Prof. R. A. S. Redmayne) and other officers for their services during the past year.

Col. R. S. Williamson seconded the resolution, which was unanimously approved.

THE SOUTH STAFFORDSHIRE AND WARWICKSHIRE INSTITUTE OF MINING ENGINEERS.

GENERAL MEETING,

HELD AT THE UNIVERSITY, BIRMINGHAM, DECEMBER 4TH, 1905.

MR. W. N. ATKINSON, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting and of Council Meetings were read and confirmed.

The following gentleman was elected:—

MEMBER—

Mr. J. T. BETTS, Civil Engineer, Redruth, Cornwall.

Mr. C. H. TREGLOWN read the following paper on "The Tangye Suction Gas-producer":- -

THE TANGYE SUCTION GAS-PRODUCER.

By C. H. TREGLOWN.

Producer-gas.—The pressing requirement of the present day is economy, and this great desideratum, in order to meet competition and to be equal to the demands of the times, is eagerly sought after in a variety of forms and ways: the necessities arising from a combination of circumstances compelling even the mining engineer to give his most serious attention to the all-important question of economy.

No comparatively recent scientific introduction, apparently of such simple character and proportions, had attracted greater or more immediate attention from the engineering and the commercial community than the suction-type gas-producer, and the excellent economic results attained therefrom can scarcely fail to make the subject interesting and important to the members of this Institute.

The manufacture of gas for heating and power purposes has been before the public in numerous types and applications for many years: in fact, the blast-furnace is a gas-producer. The several papers, which have been read, from time to time, have dealt so exhaustively with the subject that it is quite unnecessary to go deeply into the proportions and details of the combustible and heating constituents of producer-gas; and, unquestionably, the extensive application of pressure producer-gas for heating and for power has produced the most important developments in many manufactures.

Possibly, it would be somewhat difficult to say how long the gas-engine has supplied motive power with illuminating or town gas, but it is within the last 15 or 20 years, probably, that the utilization of producer-gas has been so successfully applied in the working of the modern gas-engine.

It may be well to remember that to make producer-gas, fire, air and water are essential.

Fuel.—Undoubtedly the most important factor in a suction gas-producer is the fuel used. Anthracite-coal, so far, is the

best available fuel. It must, however, possess certain qualities, which are necessary to the proper working of the generator; and it must be of such a size that no great resistance is opposed to the passage of the air and steam, and to the gas as it is produced. The size of the pieces to a very great extent determines the price which has to be paid for the coal. To get the best all-round results the coal should be in pieces of $\frac{1}{2}$ inch to $1\frac{1}{4}$ inches in size; and, for good and economical working, it is a

Fig. 1.—Tangye Suction Gas-producer.

good plan to keep the fuel in a dry place before it is used in the generator. But where it is impossible to get suitable anthracite, or where it is very expensive, suitable gas-coke, in similar sized pieces, may be used.

Tangye Suction Gas-producer.—Fig. 1 shews a Tangye suction gas-producer plant, capable of supplying a gas-engine developing a maximum of 78 brake-horsepower, with a con-

sumption of less than $\frac{3}{4}$ pound of coal per brake-horsepower per hour. It is not unlikely that it may occur to some members present, as it has to many others, as very surprising that an installation, of such small proportions and occupying so little space, should produce such remarkable results in power and economy. The apparatus (Fig. 2), consisting of a steel and cast-iron structure, may be conveniently considered as two parts, (1) the generator, and (2) the scrubber, with their several accessories and connections.

The writer, in describing the apparatus, will follow generally the order set out on the sectional drawing (Fig. 3); and, for convenience, will begin at the lower part of the generator (2).

The ash-box (1) is supplied with water, overflowing through the pipe (33), from the vapour-chamber (3). This water cools the ashes falling into it from the fire-grate, and produces steam, which, combining with the air and steam from the vapour-chamber, passes through the incandescent fuel, and forms an important factor in the quality of the gas. Hence, it is necessary to keep water always in the ash-box; and any excess flows away, by a suitable seal-pipe (34), to the drain-box (8). The ashes may be cleaned out, say, every 4 hours; and they may be removed, while the engine is at work, if this be done quickly.

The generator-casing (2) contains a refractory lining of fire-clay blocks, so as to be easily renewable. The fire-brick lining is separated from the generator-casing by a space, which is filled with any suitable material, such as foundry-sand. This sand-packing keeps the lining in place, and fills up any small air-spaces or cracks that might occur in the fire-bricks. The bottom row of fire-bricks is the one that chiefly requires to be renewed, as it is here that the most intense heat of combustion takes place. One plant has been in use for two years, and the fire-brick lining has not yet needed renewal. Just below the fire-brick lining is the fire-grate, containing the fire-bars, spaced so as to allow the ashes to fall through, as their further use in the generator is not required.

The vapour-chamber (3) is kept nearly full of water, through the water-inlet (32), a constant level being maintained by an overflow-pipe (33). The water in this chamber is heated to a suitable temperature by means of the hot gas coming from the generator, and by the radiation of heat from the incandescent

fuel in the same. Air is drawn, from the inlet-pipe (18), across the heated water, taking up steam on its way. The gaseous mixture passes down the steam-and-air pipe (19) into the ash-box (1), and through the fire-bars, where it becomes decomposed in contact with the incandescent fuel.

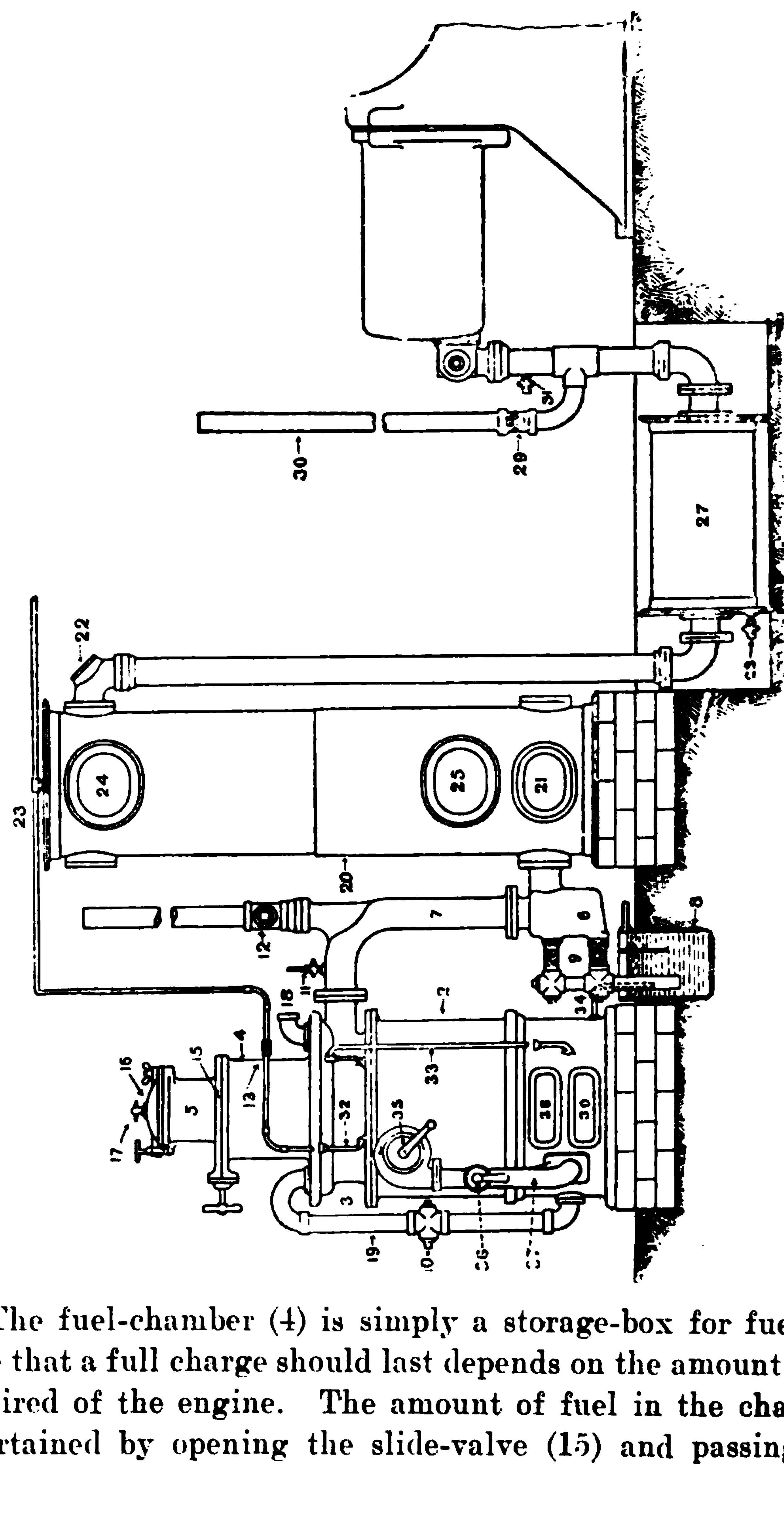

FIG. 2.—ELEVATION OF A TANGYE SUCTION GAS-PRODUCER.

The fuel-chamber (4) is simply a storage-box for fuel. The time that a full charge should last depends on the amount of work required of the engine. The amount of fuel in the chamber is ascertained by opening the slide-valve (15) and passing a rod

through the poking-hole (17) in the charging-hopper cover (16) until it touches the fuel, taking note of the length of the rod inside, removing the rod quickly, and replacing the plug (17).

The charging-hopper (5) is used for charging the fuel-chamber (4) and the generator (2). There is a slide-valve (15) at the bottom and a cover (16) at the top. When charging, the valve (15) must be closed before the cover (16) is opened; then, the hopper should be almost filled with fuel, and the cover (16)

FIG. 3.—SECTIONAL ELEVATION OF A TANGYE SUCTION GAS-PRODUCER.

closed; and, when the valve (15) is opened, the charge drops into the fuel-chamber. The valve and the cover must never be opened at the same time, and the poking-plug must always be replaced in the cover, or a stoppage of the plant will take place.

The water-seal box (6) is only brought into use when the plant is stopped. The drain-cock (9) on the lower pipe is then closed, causing the water coming from the scrubber (20) to overflow to the higher pipe (26), and thus forming, by means of the division-plate inside the seal-box, a water-seal between the generator

and the scrubber. This arrangement is very important in large plants, as it prevents any diffusion of gas taking place between the scrubber and the generator, and thus impoverishing the gas in the scrubber. The water-supply to the scrubber must not be shut off until the drain-cock (9) has been closed for a few minutes, so as to be quite certain that the water-seal has been made. The connecting-pipe (7) is used for conveying the gas from the generator to the seal-box and scrubber.

The overflow-pipes (34, 9 and 26), from the ash-box (1) and the scrubber (20) are carried into the drain-box (8), wherein the dust which comes from the gas is collected, after having been cleaned in the scrubber. The dust, which thus collects, must be taken out about twice a week, otherwise the outlets of the overflow-pipes will be stopped. The use of the drain-cock (9) has been already explained. The regulator-cock (10) is placed on the steam-and-air pipe (19). The gas is tested at the trial-cock (11). The blow-off cock (12) is used when lighting up the plant, and when the gas-engine is stopped for a short time. The cocks (13 and 14) regulate the supply of water to the vapour-chamber (3), and the scrubber (20), respectively. The fuel-chamber valve (15) is referred to in the description of the charging-hopper (5). The hopper-cover (16) contains a plug closing the poking-hole (17), through which a long rod is passed to ascertain the height of the fuel in the generator (2), or to break down the fuel, if it should become arched. Air is drawn through the air-inlet (18) into the vapour-chamber (3). The steam-and-air pipe (19) has been alluded to in the description of the vapour-chamber (3).

The coke-scrubber (20) is used for washing, cleaning and cooling the gas after it has come from the generator (2). The gas enters it at the bottom, and passes upward through the coke, meeting a spray of water (which keeps the coke moist) on its way to the outlet at the top of the scrubber. The coke should be used in pieces about 6 inches in size, and should be washed before being put into the scrubber, so as to free it from dirt, as much as possible. It must, also, be renewed about once in six months. The quantity of water passing through the scrubber should be sufficient to keep, at all times, the top of the scrubber quite cool to the hand when placed in contact with it. There are two cleaning-doors (21 and 22) on the scrubber.

The water-pipe (23) conveys water to the vapour-chamber (3) and to the scrubber (20). There are two coke-doors (24 and 25) on the scrubber.

The upper drain-pipe (26) conveys water from the water-seal box (6) to the drain-box (8). The expansion-chamber (27) should be placed close to the gas-engine. It is used for reducing the suction of the engine upon the generator, thus enabling a more even flow of the steam and air to take place through the fuel in the generator. The drain-cock (28) must be opened once a day, when the gas-engine is not running, to allow of any water, that may have accumulated in the expansion-chamber (27), running off.

The blow-off cock (29) is used when lighting up the generator, and allows smoke, etc., to pass into the atmosphere, through the blow-off pipe (30). The trial-cock (31) is used for testing the gas.

The water-inlet (32) passes the water from the water-pipe (23) to the vapour-chamber (3); the overflow-pipe (33) conveys the surplus water to the ash-box (1); and the overflow-pipe (34) conveys the excess water from the ash-box to the drain-box (8).

The fan (35) is only brought into use when starting the generator (2), enabling the fuel to be brought quickly to incandescence, and immediately afterwards good gas can be obtained. The air passes through the stand-pipe (37), fitted with the cock (36). The lower part of the generator (2) is fitted with the fire-grate door (38), and the ash-box (1) with the ash-box door (39).

Method of Working.—Having explained the construction and principal elements forming a complete suction gas-producer, the writer will now describe the method of starting and the action during the working of the same in connection with the supply of gas to a gas-engine.

Supposing the generator to be quite empty and cold, some shavings and fire-wood are placed upon the fire-bars and lighted. The ash-box and fire-grate doors are then closed and the hand-driven fan set slowly in motion. This forced draught will cause the fire to burn quickly, the fumes and smoke from the same passing upward through the blow-off pipe (the cock on which is opened) to the atmosphere. After the wood is well alight, fuel is fed into the generator at short intervals through the charging-hopper. These operations are continued until the

generator is sufficiently filled, and the fuel in the same becomes incandescent; blowing is, however, continued until good gas is obtained at the trial-cock near the generator, and at the trial-cock near the gas-engine. When good gas has been obtained, the various cocks and valves are put into their proper positions, and the gas-engine started in the usual manner.

During the operation of blowing up the fire in the generator, the hot gases passing off from the fuel circulate round and through the vapour-chamber, before passing to the atmosphere. In this way, the water in the vapour-chamber becomes sufficiently heated, and, by means of the supply-pipe and the overflow-pipe, a sufficient quantity of water has passed into the ash-box.

The gas-engine having been started, the writer will explain, in a short and concise manner, the working of the generator when producing gas. At each charging stroke of the gas-engine, gas is drawn into the cylinder at a few pounds below atmospheric pressure; and this causes the following action to take place:—Air is drawn in through the air-inlet on the top of the vapour-chamber, passing over the heated water in the same, where it takes up and becomes charged with the steam or vapour produced by the heat of the gases and by radiation from the hot fuel inside the generator. This mixture of air and steam or vapour then passes down the steam-and-air pipe to the bottom of the ash-box, taking up more steam or vapour from the heated water in the same. The mixture of steam and air, through exposure to the high temperature, and on its passage through the hot fire-bars, becomes somewhat superheated.

The now somewhat superheated air and steam pass upwards through the incandescent fuel in the generator-lining, and the following reactions take place:—The steam (H_2O) is decomposed, in the presence of the incandescent carbon, into hydrogen and oxygen. The hydrogen is then free and passes off. The oxygen derived from the steam as well as that contained in the air, combines, in the first instance, with the carbon of the fuel to form carbon dioxide (CO_2); and, as this rises through the hot fuel, it is reduced to carbon monoxide (CO), two volumes of the latter being formed from one volume of carbon dioxide (thus, $CO_2 + C = 2CO$). The liberated oxygen also combines partly with carbon to form carbon monoxide.

The gas coming off from the generator is a mixture of carbon monoxide and hydrogen, largely diluted with nitrogen from the air, and to a slight extent with carbon dioxide, which has escaped reduction. There are also very small percentages of hydrocarbons, the quantity depending on the nature of the fuel used. The constituents of the gas taken from a suction gas-producer vary a little, from time to time, and the following average analysis must not be taken as the only result that can be got:— Oxygen, 0·4 per cent.; carbon dioxide, 4·6 per cent.; nitrogen, 51·7 per cent.; carbon monoxide, 22·9 per cent.; hydrogen, 20·4 per cent.; giving a total of 43·3 per cent. of combustible gases.

The hot gases, after passing through the fuel, circulate round and pass through an opening in the side of the vapour-chamber, heating the water in the same, afterwards being conveyed by means of the connecting-pipe, to the lower part of the coke-scrubber. As the gases rise upwards, they pass through the coke, which is kept moist by running water through it; the gas is thus cleaned and cooled before passing on to the expansion-chamber, which serves to lessen the pull from the gas-engine upon the flow of the air and steam through the incandescent fuel in the generator, and thus produces an even quality of gas.

Attendance.—After the generator has been set to work, it is only necessary to inspect it for a few minutes, at intervals of two or three hours, in order to supply more fuel, and to rake out any ashes that may have accumulated on the fire-bars. The working of the plant can be easily understood by an ordinary labourer; and, as only the minimum of attention is required, the expenses are comparatively *nil.* This is an important consideration, as, with a gas-plant of the pressure-type requiring a steam-boiler, a competent man must be always in attendance. With the Tangye suction gas-producer, the generator continues to make gas as required, until it is shut down for the day. There is no stoppage for charging with fresh fuel, or when clearing the ashes from between the fire-bars.

Advantages.—As before stated, pressure gas-producer plants for many years have been used for driving gas-engines in cases where economy of fuel has been of prime importance; but the initial cost, the space occupied, and the amount of attention

required, together with the necessity of having a steam-boiler and a gas-holder, prevented their general adoption, particularly for medium and small powers. The Tangye suction gas-producer has been designed to dispose of these objections. The whole plant consists of a generator, a scrubber for cleaning and cooling the gas, and an expansion-chamber.

The advantages of the suction-type of gas-producer as compared with the older form are many, and a few may be enumerated, as follows:—(1) A steam-boiler or a gas-holder is not required, and there is, consequently, no liability of explosion. (2) It does not need constant supervision; and only requires attention for a few minutes, every three or four hours. (3) It occupies only a small amount of floor-space, and requires no special foundation. (4) There is no risk of gas escaping, as it is generated by suction, at and below atmospheric pressure. (5) The apparatus may be fixed indoors, as there is no more danger from fire than with an ordinary stove. (6) Great economy of fuel, as anthracite-beans, which are cheaper than ordinary anthracite, can be used in the generator. (7) The apparatus can be re-started, after having been shut down for an hour or so, in a few minutes, and even from a cold condition in from 15 to 20 minutes. (8) The gas is generated only as it is required by the gas-engine. (9) No gas is blown or burnt to waste when the gas-engine is working on light loads. (10) The plant is smokeless, and practically free from objectionable smell. (11) The excellent economic result is undoubtedly the remarkable feature of the suction gas-producer, when used in connection with a gas-engine as a source of motive power.

The following particulars have been published* relative to the difference of the cost per brake-horsepower per hour of electricity, lighting-gas and producer-gas:—Electricity, 0·755d., lighting-gas, 0·600d., and producer-gas, 0·164d.: the cost of electric current being taken at 1·225d. per unit, lighting-gas at 3s. per 1,000 cubic feet, and anthracite-coal at £1 2s. per ton.

A number of tests, and, what is more acceptable, the results of every-day actual work with the suction gas-producer, shew that with anthracite-coal at £1 per ton, more than 10 brake-horsepower can be obtained from an outlay in fuel of 1d.

* "Electricity, Coal-gas and Producer-gas: Its Relative Costs for Power," by Mr. H. J. Ibbotson, *Journal of Gas-lighting*, 1904, vol. lxxxviii., page 689.

per hour. Around Glasgow, Scotch anthracite may be bought for 10s. per ton, and this is equal to 20 brake-horsepower at a cost of 1d. per hour.

At the Welwyn waterworks, the duty of the small installation. in a 10 hours' test by an independent engineer, exceeded 100,000,000 foot-pounds per cwt. of Welsh anthracite coal: this high result is extraordinary, as the horsepower in the water raised was less than 2.

With a larger installation on the Continent, at a test made within the last two months, the duty (although the gas-engine was working below its proper load and the mechanical efficiency was impaired in consequence) exceeded 116,000,000 foot-pounds; and, after making an allowance for partly consumed fuel, separated from the ashes, etc., the duty would exceed 125,000,000 foot-pounds. In this case, the horsepower in the water lifted was about 14.

It has recently been stated* that, for gas-engines up to 30 to 40 horsepower (possibly brake-horsepower was meant), it was advantageous, in every way, to use lighting-gas at 1s. 6d. per 1,000 cubic feet. The saving effected by using the suction gas-producer, however, is so great that it will pay almost invariably to instal it, even for sizes of gas-engines below 30 brake-horsepower.

The suction-type of gas-producer, used in conjunction with the gas-engine, is eminently applicable in numberless cases, particularly where power is absolutely required in small or large amounts; where steam is inadmissible; where steam cannot be got; where the use of steam, in consequence of cost, cannot be entertained; and where the question of economy is imperative.

Mr. J. Robson said that, up to the present time, no other fuel had been used except anthracite bean-coal and gas-coke, although experiments were being carried out with non-caking bituminous coal. Anthracite had given the best results; but, where this was not easily obtained, gas-coke had been used with satisfactory results. Where coke was used, about 25 per cent.

* *Birmingham Daily Post*, November 25th, 1905.

burn pits, the engine and indicator were placed underground, and indication was obtained by the illumination of an opening covered by ground-glass with a number painted on it. The illumination was obtained by means of incandescent lamps of 1 candlepower, and these were kept illuminated by a contact made through an extra electro-magnet, arranged to retain contact until the engineman rang off. This type seemed less advantageous than the ordinary gravity-disc type at the Fair Lady pit, because when a low number was indicated a higher one could not come into action until the lower one was cut off. With the gravity-disc type, where no retaining magnet was required, any number of sections could be used practically simultaneously, and all would be indicated. The engineman would then not go on until he received a signal from each of the sections that had signalled a stoppage. The Harrison and Woodburn installation, although used on a wet return-air road that required considerable repairs, had worked nine months, without failure, except for batteries running down; and this, of course, could happen with any system of electric signals. The springs of different strengths on which the whole mechanical part of the system depended had never given trouble, and if they did do so, they could be very easily adjusted at any time by a thumbscrew. Another advantage of this system of signalling was the ease with which a leakage could be located, for if one occurred, the section, in which it existed, was shown at the indicator, and the length of line to be examined for it was proportionately reduced. He believed that this apparatus, with small extra expense in the beginning, afforded a means of adding considerably to the safety of working a haulage-system, where two or more loading-stations were in use, besides the saving of time in looking for leakages, and so on, or where a stoppage occurred.

Mr. F. E. Buckley remarked that the diagrams* did not show how the return-signal, given by the engineman, could be passed through the line when the pushes were out of contact. The moving ground, of such a district as North Staffordshire, would damage the wires on the roads, and the incrustation of the bare wires would prevent a good contact being made in the event of a breakage and a hasty repair. In the case of

* *Trans. Inst. M. E.*, 1905, vol. xxix., page 170, Plate V.

a breakdown between two stations, a great distance apart, which disc would be operated by a signal from that point, the in-bye or the out-bye disc?

Mr. J. WILLIS replied that, if a wire was broken, there would be no signal, as in the case of an ordinary electric signal. It was impossible for a wire to break between the sections, as the spaces between the sections were only about a foot in length. The connection for the back signal was purposely omitted in the diagrams, to avoid confusion; but it was a simple ordinary series-signal with relays or dead-resistances inserted between the sections, and a battery at each end; and wherever the circuit was closed, all the bells were rung. Therefore, when the engineman gave the return-signal, he rang every bell on the roadway, the number of times corresponding to the signal-number that had given the signal to stop. A signal could be made at any point by pressing the wires together, in the same way as with the ordinary electric signal, when a signal was required to be given.

Mr. A. HASSAM said that there was a signal for each section. If the engineman signalled four rings, the attendant at No. 4 station knew that it was for him, and the others knew that it was not for them.

Mr. J. WILLIS said that about 1 volt was required, for sections not exceeding 600 feet in length, and a length of 6,000 feet would require about 10 volts. If the sections were longer, about 1¼ volts would be required; but it would depend upon the resistances inserted between the sections to raise a barrier between one section and another, and the higher the resistance the higher would be the required voltage. In an ordinary three-line signal, two cells of about 3 volts would be used.

The CHAIRMAN (Mr. A. M. Henshaw) thought that the battery-strength with electric signals did not receive the attention that it deserved sometimes; and not infrequently another battery was put into the box. If an accident broke the wires, they were indifferently repaired, often badly insulated, and occasionally touched the roof.

Mr. J. WILLIS replied that in the new system, this could not be done; for any increase of the battery-power would interfere with the working of the indicators.

The CHAIRMAN (Mr. A. M. Henshaw) said that, if it was impossible to work this new system, by adding more batteries, that was something in its favour, as it prevented the batteries from being so wrongly used as to become a source of danger. It had been found by experiment that it was possible to ignite coal-gas with the sparks from an electric battery containing six cells.

Mr. W. L. HOBBS said that in the experiments referred to by Mr. Henshaw it was found that the sparks given by 30 Leclanché cells, at the contact of a bell, would not ignite mixtures of natural fire-damp and air.

Mr. W. LOCKETT thought that it would be interesting if Mr. Willis would give the comparative cost between his system and the former systems used, giving the numbers of wires and bells, and the power of batteries required under each system.

Mr. J. WILLIS replied that the increased cost of material for a set of these signals, with a six-holed indicator, was about £6 or about £1 per hole of the indicator. It would be possible in the majority of cases to use the existing wires, bells and relays, by a re-arrangement of wiring the same: that was, by placing them in series. This would considerably decrease the cost, as the indicators and relays (which were self-contained in a cast-iron case) could be connected to the lines with little trouble.

DISCUSSION OF MR. J. W. BATEY'S PAPER ON "THE MICKLEY CONVEYOR,"* AND MESSRS. W. C. BLACKETT AND R. G. WARE'S PAPER ON "THE CONVEYOR-SYSTEM FOR FILLING AT THE COAL-FACE, AS PRACTISED IN GREAT BRITAIN AND AMERICA."†

The CHAIRMAN (Mr. A. M. Henshaw) thought that there was still more than sufficient coal to meet the demands of the country, without having to resort to mechanical or other appliances in the working of thin seams. Still, the Mickley conveyor and the Blackett conveyor must certainly appeal to them as mechanical appliances of great interest. The working of

* *Trans. Inst. M. E.*, 1905, vol. xxix., page 268; and vol. xxx., page 118.

† *Ibid.*, 1905, vol. xxix., page 449; and vol. xxx., page 116.

thin seams, as thin as 1 foot 10 inches, had been conducted for many years. The idea had prevailed that, with thin seams, no colliery could be maintained; but now, by the methods described in these papers, it was thought possible to raise from thin seams, such as the Two-feet, an output of coal from a sufficiently large area of workings, at such a cost as to enable the colliery to hold its own with those working thicker seams. He had not seen any conveyors at work, but he was surprised at the feasibility of the devices; and from the figures, which appeared to have been carefully prepared, he thought that conveyors would revolutionize the working of thin seams, where the conditions were suitable and favourable. Where the seams were flat and the roof-material good, the conveyor would, no doubt, if carefully handled, convert an unprofitable thin seam into a profitable undertaking.

Mr. W. Lockett said that where coal-cutting machinery was used a greater output could be obtained than by hand-labour. He appreciated the remark that they were bound to get a straight face with disc coal-cutting machines. In a given district, an increase of 300 tons a week might be got by machinery above that produced by hand-labour.

Mr. A. Hassam said that, some years ago, he had been engaged in the working of seams, as little as 18 inches thick. He had not had an opportunity of seeing either of the conveyors at work; but they constituted an innovation concerning which it was desirable to suspend judgment, and to keep an open mind. However, he greatly doubted whether the use of appliances of this character would invariably lead to an increased output per length of face, as compared with the ordinary system of roads at frequent intervals, although some saving might be effected in the cost of making and maintaining the roads. Every seam had its own peculiarities and the whole circumstances *pro* and *con* must be considered in each case. Mechanical appliances of this nature might be applicable and useful in thin seams, but not in the Potteries coal-field.

Mr. B. Woodworth thought that the Mickley type of conveyor might prove useful in thin seams; but it should be constructed on different lines, so as to occupy a narrower space

and be practically suitable to receive the various sizes of coals obtained, and he doubted whether the arrangement would be serviceable, except where all the production was in small pieces or was practically only rough slack. The Blackett type of conveyor was a costly appliance, and it would hardly be possible to get out a sufficient quantity to cover the cost of working it, unless it was put on a long face in a moderately thick seam; and in that case there was every facility to do the work cheaply by the ordinary system.

Mr. G. E. Lawton thought that the Mickley conveyor might be adopted to advantage under some conditions, where power was not available in thin seams of moderate inclination. As regards conveyors in general, the physical conditions of the North Staffordshire coal-field were such that it was doubtful whether they could be applied with any amount of success.

The Chairman (Mr. A. M. Henshaw) said that a most important feature was the increase of output and the reduction of the costs of datalling, roadmaking and packing, in any given length of face. The gateroads might be spaced 300 feet apart. In the south-west of England, where thin seams were worked, hudgers were employed; they went on all fours with a chain between their legs, fastened to little sledge-like boxes, without wheels: and, certainly, mechanical conveyors were an improvement upon that method.

THE NORTH STAFFORDSIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD AT THE NORTH STAFFORD HOTEL, STOKE-UPON-TRENT, JANUARY 8TH, 1906.

MR. W. N. ATKINSON IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen, having been previously nominated, were elected:—

ASSOCIATE—

Mr. JOSEPH MAGKE, Granville House, Hanley.

STUDENTS—

Mr. HARRY DAVIES, The Gables, Alsager.
Mr. STANLEY L. GROSVENOR, Eaton House, Tunstall.

DISCUSSION OF MR. B. WOODWORTH'S PAPER ON A "PROPOSED PLANT FOR WINDING 250 TONS OF COAL PER HOUR FROM A DEPTH OF 3,000 FEET."*

Mr. B. WOODWORTH said that, in the previous discussion, Mr. J. Gregory asked why a spiral shoulder-rib was used to form the groove for the dead-rope laps. It was used to form (1) a shoulder for the grooved drum-plates and the starting lap of the rope to butt against in a true spiral form; and (2) it was made of a depth that would allow of a double ring of dead laps going into it when needed, without increasing the lateral width of the drum.

* *Trans. Inst. M. E.*, 1905, vol. xxx., page 31.

Mr. J. T. Stobbs said that Mr. Woodworth suggested using the upcast shaft for drawing coal, and that either meant making the main haulage-roads into return-airways, or a complicated system of doors would be required near the bottom of the shaft. He had had experience of one pit where this condition obtained, and he did not think that a worse condition of working a mine could be introduced. He had examined Tables I. and II., and he thought that Mr. Woodworth should define some of the terms as used by him. In Table I.,* the third column was "speed per second," the next column, "energy of acceleration," but acceleration, as commonly used, meant the rate of change of speed; and in the next column it (the term acceleration) was given a value where the change of velocity was *nil*, thus involving a mathematical contradiction. There were the same discrepancies in Table II.†

Mr. John Heath said that the Koepe system was very efficient, as long as it was well looked after; and, in applying that system to deep winding, a great deal of consideration was needed. The system had done well at the colliery with which he (Mr. Heath) was connected for twenty years. When they sank No. 2 pit, it became a question whether they should put in a bigger engine; he did not think it necessary to increase the size of the engine, but as they were going to a greater depth it was deemed advisable to be careful. Compensation-drums had been tried, but the Koepe system answered as well as any of them. He thought, on the whole, that the Koepe system of winding from great depths could not be beaten.

Mr. J. Gregory said that, in theory, the Koepe was an ideal system, and enabled winding to be effected under the most economical conditions. In pits of moderate depth, it was hardly possible to devise a more efficient arrangement; and, with a balance-rope slightly heavier than the winding-rope, both the acceleration and the retardation of the load were assisted at the proper time. The Koepe winding-plant at Sneyd colliery had been described by Mr. J. T. Stobbs and himself.‡

It was in the case of deep, heavy winding that practical

* *Trans. Inst. M. E.*, 1905, vol. xxx., page 34. † *Ibid.*, page 36.

‡ "Notes on the Koepe System of Winding," by Messrs. John Gregory and John T. Stobbs, *Ibid.*, 1899, vol. xviii., page 450.

difficulties began to assert themselves; and he instanced a case in which the shaft was 2,640 feet deep, and the strain on the rope was 20 tons. It was by no means an easy matter to make a satisfactory capping for that load; and it was also difficult to obtain a balance-rope of so large a size and to ensure that it would work properly. He would like to hear the experience of other members on these points and particularly regarding the use of balance-ropes, which were now being largely applied to winding from great depths, other than those on the Koepe system.

Mr. E. B. Wain said that the important point in Mr. Woodworth's paper was the adoption of tipping-boxes, instead of the use of the ordinary cage. There seemed to be considerable objection to the rough handling that necessarily ensued to the coal in loading and unloading such boxes, when they considered the short time that was allowed for loading at the pit-bottom. To get the maximum amount of work done it followed that they must tip the stuff and empty it with rapidity. They could not deal with the stuff gently, as they could deal with it in tipplers at the screens. The stuff had to be shifted into the tipping-boxes in a few seconds; and as there would be greater breakage, the slack would be very much increased: he thought that was the worst objection to the adoption of any such system as that suggested by Mr. Woodworth. The way in which he dealt with the balance was ingenious and removed some objections.

Mr. G. A. Mitcheson said that he could not see how tipping-boxes could be practically adopted at the present time, and therefore it hardly seemed that any useful purpose would be served by discussing that part of the paper. He agreed with Mr. Heath that winding from great depths was a complicated and difficult problem. He remembered being told, several years ago, by a mining engineer, that the only difference between winding from 1,200 feet and from 2,400 feet was the question of tipping; he was convinced that that idea was false, as the difficulties increased in a greater ratio than the depth. The difficulties in winding from a great depth, at only one lift, were the rope and the capping. He had considered the question, but he had not arrived at any definite conclusion as to what was the limit of one-lift winding. Messrs. J. Heath and J. Gregory stated that the Koepe system of winding had given every satisfaction; yet

they apparently had some hesitation in applying it to a shaft 2,500 feet deep. The objection to the weight upon the cap could be overcome by adopting a system similar to that described by Mr. Woodworth, and he thought that it possessed merits. He did not quite agree with Mr. Stobbs as to the objection to winding from the upcast shaft, as coal might have to be wound from both the upcast and the downcast shaft. In Germany, where they were using the Koepe system, the outputs per shaft were comparatively small, and at none of the German pits were they winding anything like the tonnage of the outputs in this country. He saw several examples of the Koepe system, where flat ropes were used; while in the Whiting system, the flat rope was avoided. Personally, he thought that cages and pit-tubs would be used for some years. Mr. Woodworth said that 6½ tons was a paying load; but some cages ran with the smaller load of 5½ tons. He did not think that Mr. Woodworth was far wrong in his estimate of the weight of his cage; his idea as to the balance-rope was an excellent one, and he should like to see it tried. He (Mr. Mitcheson) did not think that the balance-rope underneath the cage was practicable for a depth of more than 3,000 feet; nor did he think that the over-balance of the rope would be safe in a shaft 2,500 feet deep. The tables in Mr. Woodworth's paper shewed that there was a difficulty about acceleration, and the retardation presented a similar difficulty. Steam could be put against the winding-engine, and efficient brakes could be applied; but the unequal balance-rope was a better way of obtaining retardation.

Mr. J. Heath agreed with Mr. Wain that, by the use of tipping-boxes, the different qualities of coal would be mixed and too much slack would be made; and dust would be carried into the intake roads. He did not anticipate any serious difficulty in drawing coal from the downcast as well as from the upcast shaft. At the colliery with which he was connected, the Koepe system had been used for 23 years, and he considered it a safe system of winding, and it was now winding from a depth of 2,640 feet.

Mr. J. T. Stobbs explained that his criticism on winding implied that, where there was a choice of shafts, it was bad practice to wind from the upcast.

Mr. B. Woodworth, replying to the discussion, said that the dust arising from the tipping-box system seemed to him to compel the use of the upcast-shaft, when adopting such a system of working. If anyone desired to consider that matter thoroughly, he would be glad to co-operate in working out the mechanical portion, and he had no doubt that it could be done satisfactorily, and cause no extra breakage of coal over the ordinary system, besides providing for a subdivision of five or six sorts or qualities of coal, if required. It would not be feasible to apply the system to an old pit with the ordinary arrangements, as the difficulties of remodelling would be almost insuperable; but in laying out for a new pit, or a deeper recovery at an old one, it could be dealt with in a satisfactory manner. With this system in use, the balance-ropes would run in the same shaft, and the times given in Table II.* were ample for doing the tipping in a careful manner so as to avoid undue breakage.

The Koepe system of winding was an ideal one, to a certain extent, but when they came to deal with great depths, heavy loads and over-balancing, the practical difficulties were very serious. His system was proposed to avoid those practical difficulties, and also, what was extremely important, to relieve the cap and chains of the winding-rope from all weights except that of the cage and its load. The crucial point regarding the upper balance-rope was not, in his opinion, the grinding wear from the two laps on the grooved ring; but whether the grip of rope would be sufficient to hold the maximum unbalanced weight of the lower rope (in this case, 12¼ tons) safely, during the landing operations. The unbalanced load was put on and off gradually under favourable conditions, but it could not be absolutely guaranteed except by an actual working of the system. As an alternative for the two laps, the Whiting adaptation of the Koepe system could be employed, using as many grooves as were required for safe gripping; or the winding-engine could be placed between the two shafts, when using ordinary tubs and cages for drawing, and run two winding-ropes and two separate upper balance-ropes from the drum, working the latter in the same grooves, but in the opposite direction to the winding-ropes, and with their starting ends attached to the drum in the usual way, so that no risk of slipping whatever could occur in

* *Trans. Inst. M. E.*, 1905, vol. xxx., page 36.

the latter case. If he had to deal with a depth of 2,500 feet only, he should not allow the engineman to deal with the slack rope in landing the cages at all: and, if those jerking strains were eliminated, the rope-factor of safety was practically increased by quite 50 per cent. The loads given in the paper would be more than the engineman could lift when the lower cage had settled on the catches: consequently they would be compelled to deal with the slight slack-rope space independently of the engineman; and, while so doing, the unbalanced load held by the brake would only be $2\frac{1}{4}$ tons, that being the amount of over-balance in use. The actual true solid bearing of the rope in the drum-grooves was quite 30 per cent. of its circumference, while in the pulley, the bearing would be quite 40 per cent., and that should materially increase the power of the rope to prevent crushing under heavy loads and severe strains. The drum-grooves were set out to clear the side-grinding of the ropes in working, and the travel of the ropes being 3 feet 3 inches each way from the centre-line, there was no difficulty in designing the pulley-groove so as to entirely avoid side-grinding at that point. He thought that the use of the Koepe system with heavy loads and over-balancing would become dangerous before they reached the limit of 3,000 feet; and, as over-balancing was required to facilitate acceleration at the start of the winding, and increase the retardation at the finish in a scientific manner, it was extremely desirable to use it in all cases of balance-rope working. Flat balance-ropes under the cages, without guiding pulleys, were used satisfactorily, and round ropes were also used both with and without guide-pulleys; but in deep pits the latter would be absolutely necessary.

The instance of $7\frac{1}{2}$ tons dead weight for a paying load of 3 tons was an enormous one, but if the cage and connections were made of the same weight as the paying load, and at the same time sufficient strength was retained to meet the ordinary wear-and-tear of working, he considered that was about the utmost that could possibly be safely obtained. As Mr. Mitcheson remarked, deep winding was a serious matter, the difficulties increasing much faster than the depth, and the limit of safety was reached too soon. The object of his system was to extend that limit as far as possible, consistently with efficient and economical working.

He was pleased to know that the German outputs were considerably exceeded in this country, and if we did our best we should hope to keep the first place; still, if we persisted in self-depreciation, we could not be surprised if other countries took us at our own valuation. Flat ropes for the Koepe system had the advantage in grip over round types, and that was one of the reasons for designing the rolled-steel liners with a flat-bottom, as it would give a chance of removing the liner and running a light wide flat-rope in the recess of the main drum, if that should be thought worth a trial.

Mr. G. A. Mitcheson said that Mr. Woodworth told the members that he was going to overcome the caging difficulty, by taking the cages out of the hands of the engineman, and it was not safe to do it in any other way. No doubt his scheme possessed advantages, but he (Mr. Mitcheson) took exception to the remark that Mr. Woodworth's plan was safer than the plan in vogue at a place they all knew. He presumed Mr. Woodworth's idea was that the danger arose from the slack rope; but it was quite possible to handle the cages, without having any slack rope at all. If catches were used at the bottom and none at the top of the shaft, there was no greater chance of a slack rope coming in, than if they adopted Mr. Woodworth's plan with a hydraulic ram to take hold of the cage. He thought that there was need for recommending that mechanical engineers should design the mechanical engineering work at collieries.

Mr. B. Woodworth said that the speed of winding by the Koepe system from a depth of 2,550 feet in 55 seconds, was remarkably good for such an engine and drums; but, when the permanent engine with a parallel drum, 24 feet in diameter, was used, the cross-travel of the rope for that depth would be very considerable. The caging difficulties and slack rope at landings were very troublesome; but, as Mr. Mitcheson stated, if catches were not used at the surface, they got rid of them entirely at that end, although there still remained the slight trouble of occasional jerking at the bottom (at starting up or moving decks) to be overcome. The winding-engine had to be of sufficient power to lift the dead weight of the cage, tubs, coals, and any over-balance that might be in use; and, if that was dealt with outside the winding-engine, a considerable increase

of paying load could be prepared for, and a very slight reduction of winding speed would take place. He fully endorsed the remark that deep winding would require all the best theoretical and practical knowledge of the mechanical engineer to deal with the difficulties satisfactorily, and much of the success of deep working would depend upon the mechanical part of the work being efficient and economical.

It would have been correct to have used the words "energy used in acceleration" instead of "energy of acceleration" in Tables I. and II.; and he found that there was a slip in the figures (which were approximate) of Table I., as the seventh to the eighth revolution should have given a velocity of 59¼ feet per second, instead of 58½ feet; and the ninth and tenth revolutions were approximately correct. It would have been difficult to work out the slight acceleration possible after the tenth revolution, or any variation from that point to the actual shutting-off of the steam; but some variation would take place, and cause a slight curve in the full-speed line of the diagram.*

The CHAIRMAN (Mr. W. N. Atkinson) endorsed Mr. Mitcheson's remark as to the growing importance of the mechanical engineer at collieries.

DISCUSSION OF MR. W. G. PEASEGOOD'S PAPER ON "A GOB-FIRE IN THE TEN-FEET SEAM, NORTH STAFFORDSHIRE."†

The CHAIRMAN (Mr. W. N. Atkinson) said that Mr. Peasegood advised him of the occurrence of this gob-stink in the Ten-feet seam, and he visited the colliery on the following day. At that time, the district was full of gas for more than 60 feet below the level at which the stink had been observed, and no smell of gob-stink could be detected; and, so long as the gas remained at that level, there seemed to be no possibility of an explosion. The question of putting in dams was discussed, and although there did not seem to be any actual necessity for them, it was arranged that preparations should be made so that they could be put in quickly if any change was observed. The erection of strong dams was usually essential in dealing with

* *Trans. Inst. M. E.*, 1905, vol. xxx., page 36, Plate I., Fig. 9.

† *Ibid.*, 1905, vol. xxx., page 46.

gob-fires in the fiery seams of North Staffordshire, and this case should not be regarded as a precedent for doing without them. The object of the dams was twofold: to prevent access of air, and to resist an explosion in the sealed-off district should such occur. It was, therefore, important that the dams should have great power of resistance, such as was afforded by several feet of solid stowing. This was the first case of a gob-fire in the Ten-feet seam that had come under his notice. In his report on the explosion at Talke colliery on May 27th, 1901, the Ten-feet seam was included with other seams stated to be liable to gob-fires, but that seemed to have been a mistake. The heating in this case might have been due to the altered nature of the floor of the seam, stated to have been observed when the change of dip took place. He thought that chemical action was the cause of spontaneous combustion in mines, and questioned whether pressure or friction had anything directly to do with it in most cases.

Mr. W. G. Peasegood said that, in working the Ten-feet seam, the "tops," 2 feet 6 inches thick, were left up when driving the headings forming the roof, and were got when drifting the pillars back, the "stools," or bottom part of the seam, 1 foot thick, being worked in all cases. The seam, as a whole, was of a hard nature; but, after the pillars had been cut out in this particular district, the coal was somewhat friable. There was no water, the place was dry and dusty: the ordinary temperature in a drifting district, being about 80° Fahr., and in headings opening out, about 75° Fahr. About 40 per cent. of slack was made in this district; but, taking the seam as a whole, it would yield about 30 per cent. No analysis of the coal had been made, in order to ascertain its propensity to spontaneous combustion. The character of the gob-stink, resembling the smell of paraffin, was similar to the stink which occurred in the Bullhurst seam. No signs of vapour or actual fire were perceived, the goaf was always charged with gas, and was blocked up at the bottom of the "rearers" with small coal and warrant-dirt from above. About 5,000 cubic feet of air was passing through this particular district, at a velocity of about 120 feet per minute. Only the Ten-feet seam had been worked in this area, so that there was no question of the gob-stink "seeking" through the strata from an adjoining seam. The method adopted in

working seams subject to spontaneous combustion was to charge the goaf with fire-damp, having only sufficient ventilation to keep the working-faces and goaf-edges free from gas, and this seam was worked on the panel system, as usually adopted in North Staffordshire.

He was afraid, from the discussion which had taken place at a former meeting with respect to the use of stoppings, that there had been some misapprehension. It was true that, on the plan showing the actual seat of the gob-fire, no stoppings were shewn; but, further out-bye, in connection with the same district, stoppings were already in existence. He might explain the fact that preparation-stoppings were in reserve; but, in dealing with the fire in question, it was not found necessary to seal them or to use them in any way, the measures adopted on this occasion being completely successful without them, and it was the intention at a later date to work out part of the coal to the north-east, which was now being done. Previously, about 400 acres of the Ten-feet seam had been worked at Leycett collieries without the slightest sign of heating. It had also been extensively worked at the neighbouring Silverdale and Apedale collieries, and it had also been immune from this danger. It was quite evident that, in future, the Ten-feet seam would have to be entered on the list of those liable to spontaneous combustion in North Staffordshire, and it would have to be worked with those precautions which are usually adopted in the extraction of such seams.

Mr. J. T. Stobbs said that the members were very much indebted to Mr. Peasegood for bringing before them the fact of this fire having occurred in a seam which had been recorded as immune. In the discussion that took place on the previous occasion, some questions were asked and some remarks were made which he thought might be the subject of further discussion. Mr. A. M. Henshaw asked whether an analysis had been made of the coal to ascertain if there was in it any kind of propensity to spontaneous combustion; as if it were possible for any one taking a piece of coal and analysing it to tell whether it was liable to spontaneous combustion. It had always struck him as a subject in which chemists ought to help the mining engineer, as in the state of present knowledge little or no assistance was afforded us. Perhaps Mr. Henshaw would say something about

the analysis of coal, how, by this means, he could pick out one coal that was liable to fire and another coal that was not liable. Mr. A. Hassam said that he did not agree with the writer of the paper, that the heating was due to crushing, and said that it was due to chemical and not mechanical causes; but, with a strange inconsistency, he specified three causes, all of which were physical, and not chemical, namely:—Depth, higher temperature and greater dryness.* He (Mr. Stobbs) endorsed the view that depth and its incidental increase of temperature had a direct bearing on the origin of gob-fires. As to dryness, however, he had never heard it put forward as a cause. Moisture was essential to the theory of spontaneous combustion, as due to the decomposition of pyrites; but, as to dryness, he would ask Mr. Hassam for proof of the chemical reaction set up by this cause. Mr. Wain thought that frictional causes had something to do with it, and he (Mr. Stobbs) thought so too, as the friction of the coal would grind and abrade it, and so increase the surface of oxidation very considerably. The occurrence of some gob-fires could only be explained by complex causes acting concomitantly.

Mr. E. B. Wain believed that friction would also produce a certain amount of heat, which would tend to promote chemical action.

Mr. A. Hassam said that, in one case of heating, he watched the pack pass from blackness to red heat. There was no friction, and from his experience of gob-fires he did not think that friction had anything to do with them.

* *Trans. Inst. M. E.*, 1905, vol. xxx., page 49.

MANCHESTER GEOLOGICAL AND MINING SOCIETY.

ANNUAL GENERAL MEETING,

HELD IN THE ROOMS OF THE SOCIETY, QUEEN'S CHAMBERS,
5, JOHN DALTON STREET, MANCHESTER,
OCTOBER 10TH, 1905.

MR. JOHN GERRARD, RETIRING PRESIDENT, IN THE CHAIR.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. C. MAITLAND KNEEBONE, Mining Engineer, Oakdale, Grove Park West, Colwyn Bay.

Mr. F. J. THOMPSON, Mine Manager, United Alkali Company, Fleetwood.

ASSOCIATE MEMBER—

Mr. EDWARD THOMAS MELLOR, Geological Survey Office, P.O. Box 435, Pretoria, Transvaal.

STUDENT—

Mr. CHARLES OLIVER CROSS, 2, Percy Road, Wrexham.

The Annual Report of the Council was read as follows:—

ANNUAL REPORT OF THE COUNCIL, 1904-1905.

The Council, in presenting the sixty-seventh Annual Report on the position and work of the Society, have much pleasure in recording the satisfactory progress which has been made during the sessional year.

The Annual Meeting and eight Ordinary Meetings were held in the Society's rooms. The attendances were very good.

The membership of the Society has been increased by the election of 2 honorary members, 39 members, 3 associate members, 1 associate and 3 students, amounting to a total increase of 48. The losses by death and resignations amount to 13, of which death claims 6. As compared with the preceding year, there has been a net gain of 35 members.

Among the deaths, which the Council regretfully record, are those of Mr. George Peace, the late managing director of the

Astley and Tyldesley Collieries, Limited, who for many years was a member of the Council; Mr. H. H. Bolton, a colliery proprietor and a member of the Society for many years; Mr. Thomas Banks; Mr. W. Holding; Mr. C. G. Jackson; and Mr. W. W. Millington.

Mr. Mark Stirrup, F.G.S., and Mr. Herbert Bolton, F.R.S.E., were nominated by the Council to become honorary members, in consideration of their valuable services to the Society, and were duly elected at the November meeting.

The classification of the membership is shewn in the following table:—

Classification.	Non-federated Members.	Federated Members.	Totals.
Honorary Members	11	—	11
Members, inclusive of Life Members	80	175	255
Associate Members	—	3	3
Associates	—	2	2
Students	—	7	7
Totals ...	91	187	278

In his Presidential Address, Mr. John Gerrard referred to the federation of the Society with The Institution of Mining Engineers, and to the great advantage which the Society now possessed for promoting its objects, namely, the collection and diffusion of knowledge respecting geology and mining; also to the many local geological problems which remain to be solved; the working of seams of coal; the temperatures met with at great depths both at home and abroad; power-transmission in mines by compressed air and by electricity; and to the great improvement in the death-rate of persons employed in connection with the mining industry, as shewn by Government statistics.

During the session, valuable papers and short communications have been read before the members on geological subjects by Mr. James Ashworth, Mr. Walter Baldwin, F.G.S., Prof. W. Boyd Dawkins, M.A., D.Sc., F.R.S., J.P., etc., and on mining, electrical and mechanical engineering subjects by Mr. James Ashworth, Mr. Joseph Dickinson, F.G.S., Mr. Gerald H. J. Hooghwinkel, Mr. Arthur Ross, F.C.S., F.I.C., Mr. John J. Whitehead, Mr. G. J. Williams, H.M.I.M., F.G.S., and Mr. George H. Winstanley, F.G.S. An instructive discussion on the various methods of capping wire-ropes was introduced by the President, Mr. John Gerrard.

Mr. James Ashworth exhibited specimens of coal-dust obtained from the Morrissey mine, British Columbia; and Mr. John Gerrard exhibited fossil remains and specimens of coal obtained from the new coal-winning at Dover; also specimens of coal-dust found in the Morrissey, Shelton and Broad Oak collieries respectively. A model of a roller belt-conveyor was exhibited by Mr. Wm. Hy. Johnson.

The complete list of the papers and other contributions is as follows:—

"Notes on the Crow's Nest Coal-field, British Columbia." By Mr. James Ashworth.

"Outbursts of Gas and Coal at the Morrissey Collieries, British Columbia." By Mr. James Ashworth.

"The Hunter V. Mine, British Columbia." By Mr. James Ashworth.

"*Prestwichia anthrax* and *Belinurus lunatus* from Sparth Bottoms, Rochdale." By Mr. Walter Baldwin, F.G.S.

"A Section of the Glacial Deposits met with in the Construction of the New Docks at Salford." By Prof. W. Boyd Dawkins, M.A., D.Sc., etc.

"The Permian and Carboniferous Rocks in a Section in High Street, Chorlton-on-Medlock, Manchester." By Prof. W. Boyd Dawkins, M.A., D.Sc., etc.

"Mountain Tunnelling." By Mr. Joseph Dickinson, F.G.S.

"Church in Coal-mines." By Mr. Joseph Dickinson, F.G.S.

"Presidential Address." By Mr. John Gerrard, H.M.I.M.

"Electric Pumping at Collieries." By Mr. Gerald H. J. Hooghwinkel.

"The Circulation of Water in Steam-boilers." By Mr. Arthur Ross, F.C.S., F.I.C.

"Notes on Coal in the Transvaal." By Mr. John J. Whitehead.

"A Safety-brake for Hand-cranes." By Mr. G. J. Williams, H.M.I.M., F.G.S.

"A Fatality caused by Low-pressure Electric Current in a Lancashire Colliery." By Mr. George H. Winstanley, F.G.S.

The year in review being the first in which the Society has been federated with The Institution of Mining Engineers, it will be of interest to the members generally to know that the result has been beneficial to the Society. The number of new members (48) elected during the year is probably an unexampled record, while from the financial point of view the result, as shewn by the Treasurer's statement of accounts, has been equally satisfactory.

The Council desire to draw the special attention of the members to the important fact that the rules of The Institution of Mining Engineers, relating to its publications, have been amended, so as to include "applied geology" as a subject for papers. This, for the first time, places papers on practical

geological subjects on an equal footing with those on mining subjects, for insertion in the *Transactions* of The Institution of Mining Engineers, and relieves the Manchester Geological and Mining Society from the necessity of printing such papers at its own expense. It is hoped that the effect of this change will be to encourage members to continue such contributions.

The arrangements in connection with the Annual Meeting of the members of The Institution of Mining Engineers, held in the Town Hall, Manchester, by the kind permission of the Lord Mayor (Sir Thomas Thornhill Shann), on September 13th, 1905, and the excursions made to various works in the neighbourhood on September 14th, 15th and 16th, 1905, were made by your Council; and Sir Lees Knowles, Bart., M.P., one of your representatives, was elected to the office of President of the Institution for the year 1905-1906.

On July 22nd, 1905, the members made an excursion to Underbank and Langsett, near Penistone, to revisit the Sheffield Corporation's water-works in the Little Don valley, under the leadership of Mr. William Watts, Assoc.M.Inst.C.E., F.G.S., the engineer of the works. Mr. Watts addressed the members present, and described the scheme generally; and, with the aid of detailed drawings, illustrated the progress made from time to time during the construction of the works, extending over a series of years.

The usual presentations from kindred societies with whom transactions and periodicals are exchanged continue to be received; and these, together with the Library, are available for reference on week-days between the hours of 9·30 a.m. and 5·30 p.m., except on Saturdays, when the rooms are closed at 1 p.m.

In conclusion, your Council desire to express their indebtedness to all those who have so ably assisted by reading papers and taking part in the discussions thereon, and it is hoped that the members generally will endeavour to bring the Society to the notice of their friends, and otherwise assist in maintaining the high reputation of the Manchester Geological and Mining Society.

The HONORARY TREASURER (Col. G. H. Hollingworth) presented the annexed Statement of Accounts and the balance-sheet for the past year.

Dr. THE TREASURER IN ACCOUNT WITH THE MANCHESTER GEOLOGICAL AND MINING SOCIETY, FOR THE YEAR ENDING SEPTEMBER 30TH, 1905. **Cr.**

	£	s.	d.	£	s.	d.	£	s.	d.
Sept. 30th, 1904.									
To Balance in bank							105	12	6
,, ,, in Secretary's hands							6	14	4
Sept. 30th, 1905.									
To Members' subscriptions :—									
Arrears				30	0	0			
Current :									
1 Life-composition				15	0	0			
Donation, Dr. Black...	2	2	0						
157 Members	330	16	0						
3 Associate Members	6	6	0						
2 Associates ...	2	10	0						
7 Students	8	15	0						
50 Non-federated Members ...	50	2	0						
3 Subscribers ...	3	0	0						
				403	11	0			
In Advance				3	2	0			
							451	13	0
To Dividends :—									
Birkenhead Railway				22	16	0			
Lancashire and Yorkshire Railway				20	17	10			
							43	13	10
To Bank-interest, less commission							1	14	6
To Hire of rooms							3	8	6
To Sales of *Transactions*							1	15	0
							£614	11	8

	£	s.	d.
Sept. 30th, 1905.			
By Rent, wages, and expenses of rooms	133	19	8
,, Printing and stationery	26	15	3
,, Postages, etc.	16	14	6
,, Reporters	10	10	0
,, Library	5	12	2
,, Sundry expenses	11	12	9
,, *Transactions* of The Institution of Mining Engineers	175	18	0
,, Printing *Transactions*, 1903-1904	76	12	6
,, Expenses of meetings	22	11	2
,, Balance in bank	131	19	4
,, ,, Secretary's hands...	2	6	4
	£614	11	8

Dr.	£ s. d.	LIBRARY FUND.	£ s. d. Cr.
Sept. 30th, 1904.		Feb. 28th, 1905.	
To Balance, brought forward	4 17 5	By Books	3 5 8
Dec. 30th, 1904.		,, Balance, carried forward	1 13 9
To Bank-interest	0 2 0		
	£4 19 5		£4 19 5

BALANCE SHEET, SEPTEMBER 30TH, 1905.

LIABILITIES.	£ s. d.	ASSETS.	£ s. d.
Outstanding accounts, say	10 0 0	£600 Birkenhead Railway 3 per cent. Consolidated Preference Guaranteed Stock, at £122	732 0 0
Balance in favour of the Society	2,069 4 5	£733 Lancashire and Yorkshire Railway 3 per cent. Consolidated Preference Stock, at £90¼	661 15 0
		Library and furniture	500 0 0
		Cash in bank	131 19 4
		,, in Secretary's hands	2 6 4
		Arrears of subscription, £84, say	42 0 0
		Accounts owing	7 10 0
		Balance of Library Fund	1 13 9
	£2,079 4 5		£2,079 4 5

The Investments of ... it of £600 Birkenhead Railway 3 per cent. Consolidated Preference Guaranteed Stock, and £733 Lancashire and Y... per cent. Consolidated Preference Stock. The certificates for these are deposited at the Williams Deacon and Man... Bank, St. Ann's Street, Manchester, and were inspected by us on October 10th, 1905.

Audited and found correct, October 10th, 1905.

GEO. H. HOLLINGWORTH,
Honorary Treasurer.

JON. BARNES,
G. H. WINSTANLEY, } *Auditors.*

The Retiring President (Mr. John Gerrard) said that the accounts were most satisfactory and reflected great credit on the Society's indefatigable treasurer, Mr. Hollingworth. There was a cash-balance in favour of the Society of £130; there was about £2,000 in reserve; and, without taking account of stock, library, etc., there was some £1,500 to the good.

The report and accounts were unanimously approved, on the motion of Mr. Charles Pilkington, seconded by Mr. R. Winstanley.

ELECTION OF OFFICERS, 1905-1906.

The following officers were unanimously elected for the ensuing year:—

President:

Mr. Henry Bramall, M.Inst. C.E.

Vice-Presidents:

Mr. John Ashworth, C.E.	Mr. D. H. F. Mathews, H.M.I.M.
Mr. George B. Harrison, H.M.I.M.	Mr. Charles Pilkington, J.P.

Honorary Treasurer: Mr. G. H. Hollingworth, F.G.S.

Honorary Secretary: Mr. Sydney A. Smith, Assoc.M.Inst.C.E.

Councillors:

Mr. H. Stanley Atherton.	Mr. George H. Peace, M.Inst.C.E.
Mr. C. F. Bouchier.	Mr. William Pickstone.
Mr. Vincent Bramall.	Mr. P. C. Pope.
Mr. A. Dury Mitton, Assoc. M.Inst.C.E.	Mr. Alfred J. Tonge.
	Mr. Jesse Wallwork.
Mr. W. Ollerenshaw.	Mr. L. B. Wells, M.Inst.C.E.

Mr. George H. Winstanley, F.G.S.

Honorary Auditors:

Mr. J. Barnes, F.G.S.	Mr. George H. Winstanley, F.G.S.

Mr. Henry Bramall, in taking the presidental chair, thanked the members for having placed him in the responsible position of President, and said that he would do his best to fulfil the duties

satisfactorily. He was very pleased to think that he would have the assistance of the members of the Council and the officers of the Society, and but for that assurance he would hardly have dared to undertake such responsibilities. He might find it difficult to attend all the meetings, but he asked for their forbearance on the occasions of his absence.

He (Mr. Bramall) had pleasure in proposing a vote of thanks to the Retiring President. The members were very much indebted to Mr. John Gerrard for the interest that he took and had always taken in this Society. He had fulfilled the duties of his office, during a year which had been rather eventful, in a way that had been perfect.

Mr. C. Pilkington, in seconding the motion, said that Mr. Gerrard had done a great deal for the Society. During the visit in September of The Institution of Mining Engineers to Manchester, he worked exceedingly hard, and the result of his labours was apparent in the great success of the gathering.

The vote was unanimously passed.

Mr. John Gerrard briefly responded, and said that he took the vote of thanks to include also the members of the Council and officers of the Society. Those gentlemen had done far more than he had done, and their services had been very willingly rendered.

The President (Mr. H. Bramall) said that the late Honorary Secretary, Mr. William Saint, had served the Society so faithfully that he had great pleasure in moving that the best thanks of the Society be given to Mr. Saint for his services.

Mr. Joseph Dickinson said that he had very great pleasure in seconding the motion. Mr. W. Saint had been Honorary Secretary for about 10 years, and he had discharged the duties most faithfully and assiduously.

Mr. John Ridyard supported the motion, which was carried unanimously.

DISCUSSION OF MESSRS. W. C. BLACKETT AND R. G. WARE'S PAPER ON "THE CONVEYOR-SYSTEM FOR FILLING AT THE COAL-FACE, AS PRACTISED IN GREAT BRITAIN AND AMERICA,"* AND MR. J. W. BATEY'S PAPER ON "THE MICKLEY CONVEYOR."†

The PRESIDENT (Mr. H. Bramall) said that the Mickley conveyor appeared to be very much like the old system that was in vogue before he came into the trade—a belt, chain and sled, to run across the face, and lead the coal into a skip at the end of the face. It seemed to be a revival of that system modernized, and made to suit present requirements. The other system, described by Messrs. Blackett and Ware, was an entirely new departure, so far as he knew, as the coal was conveyed across the face in a kind of trough, fitted with scrapers, instead of taking the wagon along the face. It did not appear to him that these methods would be valuable to miners in their immediate neighbourhood; but there were parts of Lancashire where thin mines were being worked, and some gentlemen from those parts would do well to investigate carefully what had been written and said about these conveyors, especially as to their suitability for this district. It appeared to him, that in a mine under 24 inches, or even under 30 inches, high, that some such system as those described might be usefully and economically worked in conjunction with mechanical coal-cutters or otherwise.

Mr. CHARLES PILKINGTON said that their mining engineer, Mr. P. L. Wood, had inspected the Mickley conveyor in operation in the north of England, where it seemed to be working very well; but it would be rather difficult to apply the system in their own mines. The conveyor could not easily be moved forward as the face advanced, and a very good floor and good roof were necessary. If they were working an exceedingly thin seam, with a long face, then he thought it would pay; but whether it would pay in their Lancashire workings he did not quite know. There was another means of conveying coal across the face that they had tried, which was not quite a success at first, but they were trying it again with a different arrangement. It was very

* *Trans. Inst. M. E.*, 1905, vol. xxix., page 449; and vol. xxx., pages 116 and 278.

† *Ibid.*, 1905, vol. xxix., page 268; and vol. xxx., pages 118 and 278.

much like the old chain-system, sliding the tub, boat-like along the coal-face, one rope being attached to two boats; and as one boat went down the other came up. It was uncertain whether it would be successful; but at present, it was out of use, because the face where it was tried was now stopped.

Mr. A. J. TONGE said that he had seen a Blackett conveyor working in a Yorkshire colliery, and he came away with the impression that it was quite suitable for seams with a fairly good roof, varying in height from 18 inches to 30 inches. He found that the difficulties of adapting the Blackett conveyor in a seam, 18 inches thick, would be of such a character that they could hardly be surmounted. He consequently adopted, at the Hulton colliery, a tub-system which answered well in a seam, 18 inches thick. They were now using six of these conveyor-tubs, running along the face for a distance of about 150 feet, and they had discontinued the intermediate drawing-roads. Instead of having drawing-roads about 42 feet apart, the main roads were now made about 150 feet apart. The results so far had proved very satisfactory. The wheels of the conveyor-tub were placed at the extreme ends, the box-portion being fixed in a low position; and, consequently, the tub ran almost close to the floor of the mine, and big lumps of coal could be rolled into the tub instead of having to be lifted. He did not think that it was necessary to go into the costs, but the system had been fairly satisfactory.

Mr. JOHN GERRARD asked Mr. Tonge, with regard to the use of the Blackett conveyor, what was the least distance between the packs and the face that he considered would be required along the face, and within which the conveyor would work. He was told that it was necessary to have a width of not less than 13 feet, from the face, resting on timber. Apparently, this would be a difficulty, when working at a considerable depth, and with anything but a good roof.

Mr. A. J. TONGE replied that the distance between the face and the pack-walls would not be far from 12 feet, at the particular time when the conveyor wanted moving. Ordinarily, the average distance would not exceed 6 feet; but he thought that it was possible to move the conveyor every shift, and, in that way, it might be possible to keep it within, say, 8 feet of the

face. He found that, with the conveyor-tub, the packs could be kept within 8 or 9 feet of the face: this system was practically the same, as it required a straight line of face in the same way as the Blackett conveyor, and was moved systematically forward.

Mr. C. Pilkington remarked that timber could be set between the packs and the coal-face.

The President (Mr. H. Bramall) thought that Mr. Tonge's experience was likely to be that of most people working thin seams, namely that the Blackett conveyor would require too much room and be too troublesome to move; whereas the Mickley conveyor, the old-fashioned sled, could be easily moved. It was well worth the attention of those working mountain mines, who might enquire whether some modification of the Mickley conveyor could not be usefully applied. He did not think that it was a system likely to be useful generally in all mines; but it was evidently suitable for use in thin seams.

MANCHESTER GEOLOGICAL AND MINING SOCIETY.

GENERAL MEETING,
HELD IN THE ROOMS OF THE SOCIETY, QUEEN'S CHAMBERS,
5, JOHN DALTON STREET, MANCHESTER,
NOVEMBER 14TH, 1905.

MR. HENRY BRAMALL, PRESIDENT, IN THE CHAIR.

The following gentleman was elected, having been previously nominated:—

HONORARY MEMBER—
Mr. WILLIAM SAINT, H.M. Inspector of Mines, Manchester.

The PRESIDENT (Mr. Henry Bramall) delivered his inaugural address, as follows:—

minimum rate of 30 per cent., but with an increase of the maximum to 60 per cent. This maximum rate of wages was attained on February 1st, 1901; but, by that time, prices had already begun to droop; they have since continuously fallen, and there have also been reductions in the rate of wages, which now stands at 40 per cent. above the standard of 1888.

The fourth and existing Conciliation Board was formed to regulate wages from January 1st, 1904, to December 31st, 1906; and the minimum rate was raised to 35 per cent. above the standard of 1888, the maximum rate remaining at 60 per cent.; so that wages are, now, only 5 per cent. above the minimum rate.

Plate IX. and Table I. shew that in the sixteen years since 1889 a higher range of wages has been paid than in the preceding sixteen years: during the sixteen years from 1874 to 1889 inclusive, the average rate of wages was 4 per cent. above the standard of 1888, whereas, for the sixteen years from 1890 to the end of the present year, the average rate of wages was 40 per cent. above the same standard.

TABLE I.—SHEWING THE VARIATIONS IN COLLIERS' WAGES IN RELATION TO THE BASIS OR STANDARD WAGES OF 1888.

Date of Change.	Character of Change.	Amount of Change.	Variations above or below the Basis or Standard Wages of 1888.	Date of Change.	Character of Change.	Amount of Change.	Variations above or below the Basis or Standard Wages of 1888.
		Per cent.	Per cent.			Per cent.	Per cent.
1874 May 1	Reduction	15	17½	1888 Nov. 1	Advance	5	10
1876 April 6	Do.	15	2½	1889 July 1	Do.	5	15
,, Aug. 1	Do.	7½	– 5	,, Oct. 1	Do.	5	20
1878 June 1	Do.	5	–10	1890 Jan. 1	Do.	10	30
1880 Dec. 1	Advance	5	– 5	,, Mar. 21	Do.	5	35
1881 April 6	Do.	5	0	,, Aug. 6	Do.	5	40
,, Aug. 1	Reduction	10	–10	1894 Aug. 1	Reduction	10	30
,, Nov. 1	Advance	10	0	1898 Oct. 5	Advance	2½	32½
1882 Nov. 1	Do.	10	10	1899 April 5	Do.	5	37½
1885 May 1	Reduction	10	0	,, Oct. 4	Do.	2½	40
,, Nov. 1	Advance	10	10	1900 Jan. 3	Do.	5	45
1886 June 1	Reduction	10	0	,, Oct. 3	Do.	5	50
,, Dec. 1	Advance	10	10	1901 Jan. 1	Do.	5	55
1887 May 1	Reduction	10	0	,, Feb. 1	Do.	5	60
1888 Jan. 1	Advance	10	10	1902 July 2	Reduction	10	50
,, April 2	Reduction	10	0	1903 Dec. 22	Do.	5	45
,, Oct. 1	Advance	5	5	1904 Aug. 16	Do.	5	40

There is another point of view from which this question of increased wages may be considered, and that is, the relation

that wages bear to the total cost of production. If the average of five years' periods be taken, they shew that the percentage of the whole cost, which was paid directly in wages, was as follows:—1875-1879 inclusive, 66·25 per cent.; 1880-1884 inclusive, 66·26 per cent.; 1885-1889 inclusive, 67·79 per cent.; 1890-1894 inclusive, 70·74 per cent.; 1895-1899 inclusive, 70·74 per cent.; and 1900-1904 inclusive, 72·63 per cent. This shows that there has been an increase of about 6¼ per cent. in wages during the past thirty years.

The deduction which I draw from these figures is that we have got to face a permanently higher rate of wages in the future, and that labour will be an even more important item in the cost of production than it has hitherto been. We shall find it necessary to follow the example set by American engineers, and we shall have to economize labour, not by reducing the rate of wages paid to the men, but by utilizing to better advantage this costly labour; and by adopting any improvements, mechanical or otherwise, which will tend to reduce the amount of manual labour involved in the production of a ton of coal, and to render the labour, we employ, more efficient, and consequently more economical.

The consideration of the way in which this can be done opens up a wide field for study. The working of a mine is a very different matter from the working of a mill or a manufacturing establishment. The conditions in mines are constantly varying, and are at all times such as render difficult the adoption of any labour-saving appliances, except those of the simplest character. I purpose to glance briefly at one or two directions in which labour-economies may possibly be effected, and suggest a few points for your consideration.

The first thing that occurs to me is, that greater attention might be paid to proper organization, systematization and concentration. In some cases, especially in collieries which have been opened for some considerable time, the coal-getters are, more or less, scattered about the mine, entailing the maintenance of great lengths of roads, both for conveyance and air-roads, weakening the efficiency and increasing the cost of supervision. Economy may be effected by concentrating the men as much as possible, lessening the length of working-faces to be kept open

and also the length of drawing-roads. Further, these roads should be so arranged that the conveyance-men (wagoners, jiggers, and so on) may be kept fully employed, and that they do not spend a large portion of their time in waiting for something to do. By diminishing the length of roads to be maintained, they can be kept in better order with fewer on-cost men or datalers, and by concentrating the miners they can be kept under better supervision. The firemen, not having to spend so much time in travelling from one place to another, will have more leisure to see that the working-faces and roads are kept in safe condition, that the colliers have a more regular supply of tubs, and that the whole routine of the mine is more systematically and regularly carried on.

It is generally admitted that the severest work of a collier is the holing and cutting of the coal, where it is at all hard, and it is a point well worth considering, how far mechanical coal-cutters can be introduced with advantage to supersede manual exertion. Some excellent practical papers on coal-cutters have been read before this Society; and papers recording further experience of their use in Lancashire mines, and especially setting forth how the difficulties in their application had been surmounted and the economical results were obtained, would be very welcome. Lancashire does not appear to be in the fore-front in the use of these machines, for, on reference to Mr. John Gerrard's report for the past year, I find that there are only 46 machines of all kinds in use in this district, and less than 220,000 tons of coal were got by them in 1904. Probably the difficulties with which we have to contend in this coal-field, such as bad roofs and floors, the steep inclination, and the disturbances and faults, together with the fact that in many of our mines the coal is moderately soft, may have a good deal to do with the slow progress of machine coal-cutting.

Several varieties of machine drills have been introduced, with economy of labour, and there may be room for the use of more of these handy little machines.

Heading machines, for cutting straight roads, have been of great service in some collieries in the Midlands. I may say, however, that I did not succeed with the one that I tried, the coal bursting off as soon as cut and repeatedly burying the machine.

After the coal is cut and filled it requires hauling from the face to the pit-shaft; and, in this work, a very large amount of manual labour is employed. In this district, it appears, from the figures given by Mr. John Gerrard in his report, that about 17 per cent. of the total output is brought to the pit-shaft by manual labour; and, in what may be termed secondary haulage, that is, the bringing of the coal from the face to the main haulage, that about 67 per cent. is moved by men and horses. Is it not possible that a large amount of this manual and horse-labour might be dispensed with, and replaced by mechanical methods, with considerable economy? It seems to me that it might be so, especially when we remember that most collieries have now compressed-air plant available for the transmission of power into the innermost recesses of the mine. The adoption of small portable hauling-engines, wherever a lower-side place has to be worked, and so dispensing with the slow and laborious hand-crab winding, also tends to economy. We recently had a discussion on two systems of conveying coal across the face, which were said to give economical results, particularly in thin seams. It appears to me advisable to get mechanical haulage of some kind as near as practicable to the coal-face, and to dispense to the utmost possible extent with manual and horse-labour, and, so, get rid of that bone of contention "long drawing."

In the winding and handling of the coal on the pit-bank, automatic arrangements may result in some saving, by enabling a larger output of coal to be dealt with by fewer men. Creepers, conveyors, travelling belts, and endless ropes or chains are all useful, where material has to be moved; but judgment is required in adopting such appliances and it is only by system and organization that the adequate advantage can be gained by their use. In some cases, it is possible to economize labour in shunting railway-wagons by judicious arrangement of the sidings, so as to take advantage of gravity.

I do not mention any of the general economies in the working of collieries, as my object has only been to call attention to the wages question and to indicate some of the directions in which I think it possible that labour may be better utilized. We may venture to hope, too, that the more extended use of

machinery will have the result of improving the lower class of workers in and about our mines, and providing us with a more intelligent race of workmen, whose faculties will be sharpened, and who will show a degree of perception and adaptability that will fully justify and compensate for the increased rate of wages that they will receive.

Mr. JOHN GERRARD (H.M. Inspector of Mines) said that he was sure that the Society would have, during the coming year, the fullest benefit of Mr. Bramall's vast experience, and of the attractive influence which his presence in the chair would exercise upon the members generally. He (Mr. Gerrard) stated that, in his view, it was in the interests alike of the owner and the worker to furnish the men with the fullest opportunity of getting the greatest amount of coal; and if, by that means, the worker could obtain a large daily wage, the owner would also obtain a fair return on the capital invested. He moved that a hearty vote of thanks be given to the President for his address.

Mr. ROBERT WINSTANLEY, in seconding the resolution, thought that it would be better to defer the discussion until the address was printed in the *Transactions*.

Mr. JOSEPH DICKINSON, in supporting the resolution, remarked that the stirring address of Mr. Bramall, which applied to the every-day life of mining, one of the two objects of the Society, was a practical paper, and reminded him that Mr. John Knowles, when President of the Society, framed his address on similar lines. He (Mr. Dickinson) was happy to say that an improvement in the coal trade followed it, and he hoped that the same result would follow Mr. Bramall's address.

Mr. J. S. BURROWS, in supporting the motion, thought that Mr. Bramall was on the right track. He had been trying to make the work of the coal-miner more comfortable and easier, and he had no hesitation in saying that such a policy would be beneficial to both masters and men. At present, a long time was occupied by the men in getting to their work, and often they had a good deal of uncomfortable travelling, so that much

of their strength was gone before they began their day's toil. He (Mr. Burrows) was also endeavouring to improve the roads in the mine, so as to facilitate the men's work and to enable them to use their strength to the best advantage.

The resolution was heartily adopted.

The PRESIDENT (Mr. Henry Bramall), after expressing his thanks for the resolution, called attention to an alarmist statement in one of the Manchester newspapers to the effect that the large number of disused coal-pit shafts, scattered within the thickly populated parts of the city of Manchester, were a hidden source of danger. He deprecated the publication of these sensational statements, and thought that there was no substantial foundation for them.

Mr. JOSEPH DICKINSON read a paper on "The Origin of Fossil Life."

MANCHESTER GEOLOGICAL AND MINING SOCIETY.

GENERAL MEETING,

HELD IN THE ROOMS OF THE SOCIETY, QUEEN'S CHAMBERS,
5, JOHN DALTON STREET, MANCHESTER,
DECEMBER 12TH, 1905.

MR. HENRY HALL IN THE CHAIR.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. JOSEPH KAY, Colliery Manager, Agecroft Collieries, near Manchester.

Mr. CECIL W. EAMES, Mining Engineer, Moss Hall Collieries, Platt Bridge, near Wigan.

STUDENT—

Mr. GEORGE ENTWISTLE, Mining Student, Birmingham University, Birmingham.

Mr. GERALD H. J. HOOGHWINKEL read the following paper on "The Generation of Electricity by the Waste Gases of Modern Coke-ovens":—

THE GENERATION OF ELECTRICITY BY THE WASTE GASES OF MODERN COKE-OVENS.

By GERALD H. J. HOOGHWINKEL.

Introduction.—More and more ironmasters begin to understand and appreciate the immense waste of energy, which is still going on, day after day, in iron- and steel-works. As witness, the huge columns of flaming gases that one may see at night in the great iron and steel centres. Very slowly, indeed, is this growing conviction acted upon: everyone waiting to see his neighbour's results, and very few acting upon their own firm belief in new practices. A single case of bad results, caused by the inexperience of the makers of the (to them new) engines, is apt to cause a halt, and in the case of blast-furnace gas, has actually done so, setting back a growing industry for several years.

However, the application of blast-furnace gases to the production of power, and electrical power in particular, is an established fact in this country, the growth of which will be witnessed during the next decade, and will probably keep pace with the urgently-required remodelling and redesigning of iron- and steel-works in the near future.

Although the experiments of Mr. B. H. Thwaite in this country opened the way, the first large undertakings of this kind were established in Germany, and at present most of the iron-works in that country and in the United States are equipped with electric-power stations deriving their power from the gases of the blast-furnaces, while many of the powerful blower-engines are driven by the same agent.

The writer has had the good fortune to take part in the design and erection of some of the biggest and earliest undertakings, namely, the gas-plant at the Ilseder iron-works, supplying also the necessary power to the Peine rolling-mills, near Hanover. The entire steel-works and rolling-mills, at Peine, are driven by electricity generated from waste blast-furnace gases, a strik-

ing example of the economy effected by modern practical applications.

But the same advantages, as regards the supply of power for driving the mechanical appliances of a modern coking-plant, with washing- and cleaning-plant near by, and even the plant at the pits, may be derived by using the surplus-gases from coke-ovens direct in gas-engines. The present method of burning the surplus-gases under old-fashioned boilers provides about 200,000 horsepower in the United Kingdom; and, if it be estimated that the direct burning of these gases in internal-combustion engines is three times as efficient, one may realize how much power that might be retained is now being wasted.

The question is one of public utility and economy, and the waste gases would provide this country with a source of cheap power, comparable to the water-power used in Canada and countries abroad. As cheap power is going to be the keystone of the existence of Great Britain as the oldest and first manufacturing country, the question is worth considering, even by men directly connected with collieries. Of course the quantities in question are not to be compared on the same lines, as blast-furnaces can supply a far greater quantity of gas for power-generation than coke-ovens. A modern blast-furnace, consuming about half the quantity of gas produced, may be expected to give about 20 horsepower per ton of pig-iron produced. Blast-furnace gas, however, is a poor gas, more like the gas obtained from modern producers, while coke-ovens produce a rich gas approaching town-gas. The importance of the power derived from coke-ovens for use at collieries may, therefore, be taken as being of the same value as the power derived from blast-furnaces for use in steel-works and rolling-mills.

Utilization of Coke-oven Gases for Power-generation.—Many, but still relatively few, coking collieries utilize the spare gases from their coke-ovens under steam-boilers, which supply steam to the auxiliary plant, and, sometimes, to continuous-running plant, namely, air-compressors and pumps. On account of their intermittent steam-consumption, it is often preferred to run winding-engines from separate coal-fired boilers.

The wasteful character of this method, as compared with the direct combustion of the gases in an internal-combustion

engine, need not be insisted upon. To estimate the magnitude of this loss, one has only to remember that, of the quantity of coke produced in Great Britain in 1902 of 10,000,000 tons, only about 10 per cent. was produced in bye-product ovens. If it be assumed that most of these gases, after being freed of tar, ammonia and benzol, are passed under boilers, about 10 horsepower per oven will be obtained.

Modern bye-product ovens yield about 78 per cent. of coke on a charge of 4 tons of coal per oven. Using water-tube boilers, 1¼ pounds of water, on an average, can be evaporated per pound of coal coked in the ovens, where the bye-products are actually being recovered. As 30 to 40 hours elapse between each charge, about 11,000 pounds of steam are generated, and about 10 brake-horsepower per oven is produced.

When burned directly in a gas-engine, taking about 25 cubic feet of gas per brake-horsepower-hour, the amount of power per oven is about 25 brake-horsepower on the engine-shaft, or twice to three times as much as when burning the gases under steam-boilers. This estimate assumes that the coal produces 15,000 cubic feet of gas per ton of coal and that 25 per cent. of the gases are available for power-purposes. This calculation shows the great saving in power and, therefore, in coal (which is now burnt under boilers at collieries) to be derived from using the spare gases in gas-engines, even in comparison with the most up-to-date steam-plant. There are many collieries, on the Continent and in the United States, where coal is not burnt in a single boiler for power-requirements: including coke-ovens, washeries, air-compressors, winding-engines, pumping-engines, etc. This implies a saving in coal of 3 to 5 per cent. on the output, a figure which must be considered, now that most managers are coming back from the old and mistaken idea "that slack costs nothing at the pit-mouth."

Generally speaking, when introducing gas-engines, bye-product ovens will be required, and the saving in efficiency alone which these ovens represent over the old type of bee-hive oven, would amount to about £2,500,000 per annum in Great Britain. Add to this, the sale of bye-products worth about 4s. 6d. per ton of coal coked, and one may realize the savings that will be derived from the wholesale adoption of bye-product coke-ovens and gas-engines.

Of course, all coals are not suitable for this coking process, as the quantity of spare gas is very variable. Many coals, with a small percentage of volatile matter, say, South Wales coals with 15 to 18 per cent., requiring a very high coking temperature, only give off enough gases to heat the walls of the coke-ovens and leave no surplus gases. Of course, by suitably heating the flues, or, better still, the air-supply (regenerative ovens), it is always possible to obtain a saving in gas of about 20 per cent. From good coking coal, such as Durham, Silkstone, etc., coal, with a percentage of volatile matter varying from 20 to 30 per cent., it is easy to utilize 20 to 40 per cent. of the total gas-production for power-purposes in gas-engines. Coals with a very high percentage of volatile matter, such as Durham gas-coals, need a very much higher temperature to produce a hard coke, and, therefore, do not leave more surplus gas than coal of a medium percentage.

Another important point, influencing the amount of surplus gas, is the quantity of water present in the coal; with washed coal, often containing over 15 per cent. of water, the amount of heat and, therefore, gas, required to evaporate this water, is very considerable.

It is quite possible, and even desirable, to combine both systems, and to pass the gases, which have been partly cleaned and freed from bye-products, after heating the flues and regenerators, under steam-boilers, while the surplus-gases are taken direct through additional cleaning-plant to the gas-engines.

There is, however, another direction in which the surplus-gases may be utilized, and in the United States there are many coking-plants, which supply neighbouring townships with gas for lighting purposes. The gases are carburetted with benzol, and compressed, in order to distribute them over distant districts, as the Mond-gas Company is doing in South Staffordshire. This, of course, eliminates the objection that there are no consumers near the coke-ovens requiring the surplus-gases for lighting purposes. One must not forget that the efficiency of these gases, when used for lighting, is about fifteen times as much as when burnt under steam-boilers, and this application is, therefore, worthy of consideration.

But by far the most important field for the utilization of spare gases is the direct driving of gas-engines. Roughly speaking, the writer has found, in many cases, that the cost

per unit in coke-gas power-stations of medium size is about 0·1d. to 0·2d.

The production of cheap power at collieries is a question, gaining in importance every day, proportionately to the drop in the price of the saleable article and the increased depth of the pits. The firing of steam-boilers by means of small coal at the pit is an expensive method, and if no rubbish and refuse from the washeries are available, a very wasteful process, having regard to the low efficiency of the boilers. Even taking the value of this small coal at 2s. to 4s. per ton at the pit-mouth, the saving of coal by using gas-engines is a substantial item. Moreover, small coal and washed peas have a market value, nowadays; and it will not be long before a fuel will be made out of waste-heaps, which will, consequently, raise the commercial value of all small stuff at the pit-mouth. Every modern colliery should, therefore, either burn its rubbish and waste in gas-producers, or else compress and coke it in bye-product ovens, using the gases obtained in both processes for generating electrical power by means of gas-engines.

The Composition, Caloric Value, and Cleaning of Coke-oven Gases.—It may be useful to retrace, in a few words, the history of the blast-furnace gas-engine, the predecessor of the coke-oven gas-engine. The first experiments were carried out by Mr. B. H. Thwaite, but it seems that this investigation has not been duly followed up by engineers in this country, as they have allowed Germany to acquire a preponderant position in the gas-engine industry. During the last three years, more than 180,000 horsepower of blast-furnace gas-engines were erected in that country alone; and at the St. Louis Exhibition, a gas-engine was shewn with a capacity of nearly 2,000 horsepower in one cylinder, and of nearly 4,000 horsepower as a tandem engine.

The writer will record a few figures demonstrating the huge amount of power now being wasted. A modern blast-furnace produces per ton of pig-iron about 20 horsepower continuously, after allowing a loss of 10 per cent. during the charging of the furnace, and about 35 per cent. for heating the blast in Cowper stoves. Now, taking the annual pig-iron production at 20,000,000 tons, and allowing a saving of 3s. per ton of pig-iron,

when utilizing blast-furnace gases, the importance of the introduction of gas-engines in iron- and steel-works may be gauged. This amount of power is not only available for driving blast-engines and furnace-lifts, but it may supply gas-engines driving rolling-mills and other plant in the steel-works, working on a very variable load. This has been recently shown at the Krupp works, at Essen, where some roughing-mills are directly driven by gas-engines.

Composition and Caloric Value of Coke-oven Gases.—The composition of coke-oven gases depends on several conditions and, moreover, changes considerably during the period of coking. Two of the most important of these conditions are the amount of moisture in the coal and the air-tightness of the coke-oven walls.

The changes in the composition of coke-oven gases, during coking, are shewn by the results of experiments made by Dr. F. Schniewind, at the works of the United Coke and Gas Company, Glassport, Pennsylvania.* An analysis of the gases, taken between the exhaust-fan and the scrubbers, was as follows:—I. First 15 hours: hydrogen, 38·4 per cent.; marsh gas, 38·7 per cent.; carbon monoxide, 6·1 per cent.; hydrocarbon gases, 5·2 per cent.; carbon dioxide, 3·6 per cent.; oxygen, 0·3 per cent.; and nitrogen, 7·7 per cent. II. Last 19 hours: hydrogen, 50·5 per cent.; marsh gas, 29·2 per cent.; carbon monoxide, 6·3 per cent.; hydrocarbon gases, 2·4 per cent.; carbon dioxide, 2·2 per cent.; oxygen, 0·3 per cent.; and nitrogen, 9·1 per cent.

The gradual variations in the composition of the gas may be seen in Fig. 1.† The hydrogen curve rises in the last half of the coking process, while the marsh-gas curve falls. This shows a higher illuminating-power for all the gases generated during the first period. The rise of the nitrogen curve is probably due to the entrance of air through cracks in the ovens. Fig. 2‡ represents graphically the calorific value, specific gravity and candle-power of the gases tested in Dr. Schniewind's experiments.

An analysis of the gases from coke-ovens at the Consolidation colliery, in Westphalia, yields the following results:—Hydrogen,

* *Trans. Inst. M. E.*, 1901, vol. xxii., page 619.

† *Ibid.*, page 641. ‡ *Ibid.*, page 642.

48·9 per cent.: marsh gas, 35·8 per cent.; carbon monoxide, 7·2 per cent.; hydrocarbon gases, 3·2 per cent.; carbon dioxide, 1·2 per cent.; and nitrogen, 3·7 per cent. These results were obtained by retort-sampling, and are slightly different from those obtained in actual practice: the retort being perfectly air-tight, the amount of nitrogen is much smaller. From the point of view

FIG. 1.—ANALYSES OF COAL-GASES PRODUCED FROM OTTO-HOFFMANN COKE-OVENS.

of the value of the bye-products, the amount of nitrogen is important, as affecting the yield of ammonia. It is, however, of no use in a gas-engine, as it reduces the heating-power of the gases.

Another good example from modern Otto coke-ovens, with the latest improvements, is furnished by a sampling of the

gases from the Mathias Stinnes colliery, in Westphalia, where gas-engines of over 1,500 horsepower were erected in 1901. The coal-charge of the ovens was washed, and the amount of water was therefore considerable; and, as this process will be followed more and more with modern bye-product ovens, the sampling may be taken as representing modern British practice as well,

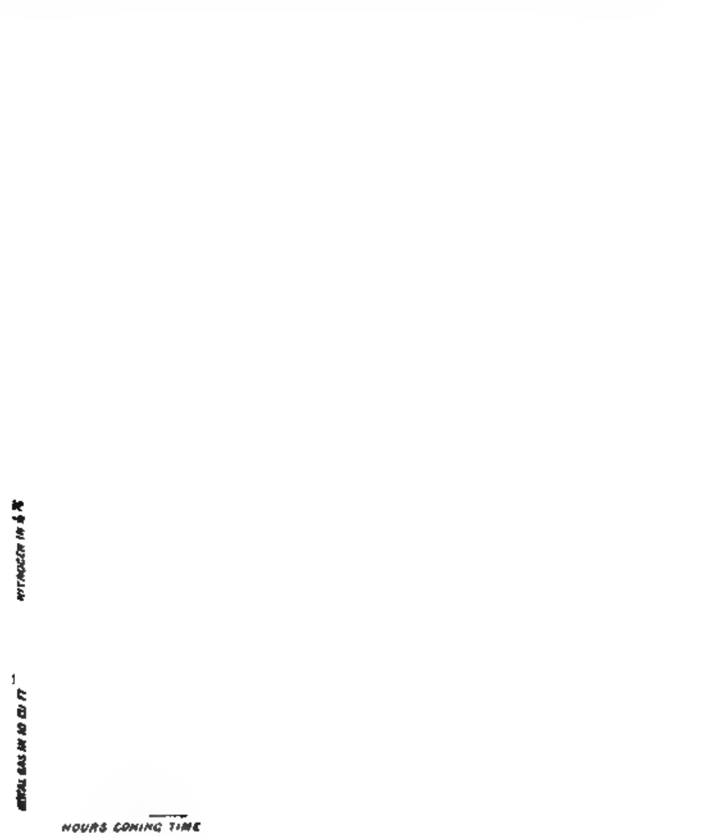

FIG. 2.—CALORIFIC VALUE, SPECIFIC GRAVITY AND CANDLEPOWER OF COAL-GASES PRODUCED FROM OTTO-HOFFMANN COKE-OVENS.

the coal being equal to best British coking coal. The coal contained 15½ per cent. of volatile matter and 7½ per cent. of ash; and it produced 75 per cent. of coke, 4 per cent. of tar, and 1½ per cent. of ammonia. The average composition of the gases was found to be as follows:—Hydrogen, 45 per cent.; marsh gas, 30 per cent.; carbon monoxide, 10 per cent.; carbon dioxide,

2·5 per cent.; hydrocarbon gases, 2·5 per cent.; and nitrogen, 10 per cent. The temperature in the oven-flues was 1,900° to 2,250° Fahr.

The result of these samplings has shown that the composition, and therefore the caloric value, of the gases varies considerably during the coking process. Of course, the number of ovens in operation tends to equalize these figures, as may be seen from Fig. 3 recording the variation of calorific value during one day, in a battery of 60 Potter coke-ovens at a British colliery. The importance of keeping the value of the gases constant will be appreciated by everyone used to the large gas-engines in blast-furnace works, and various means have been adopted for this purpose.

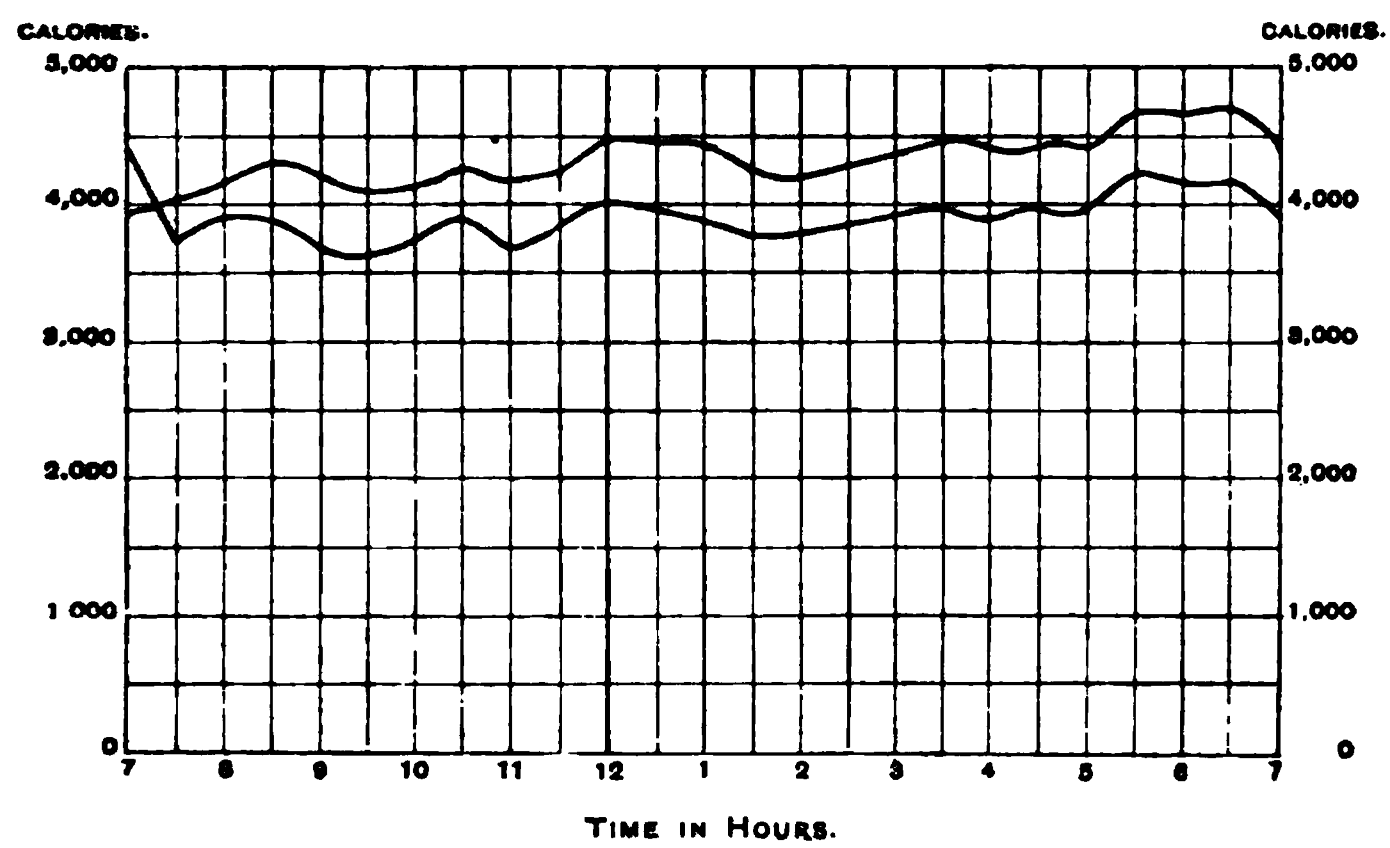

FIG. 3.—CALORIFIC VALUE FOR ONE DAY OF COAL-GASES PRODUCED FROM POTTER COKE-OVENS.

At the Mathias Stinnes colliery, two gas-mains were connected to each oven, one being the rich gas-main for the gas-engines, and the other the poor gas-main for heating the ovens and boilers. Other collieries mix the coking coal and take great care in always measuring the correct charge. A gas-tank of ample dimensions is, of course, the best guarantee of keeping the calorific value constant. The quantities and calorific values of the gases depend on the quality of the coal, the amount of moisture and the type of oven. Table I. records the results at five large coke-oven gas-plants, the figures giving the average results of everyday practice.

TABLE I.—ANALYSES OF SPARE GASES FROM COKE-OVENS.

Name of Colliery ..	Stumm.	Julien.	Borsig.	Theresien.	Johannis.
Type of Oven	30 Under-flue.	300 Otto.	76 Regenerative.	120 Regenerative.	
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Hydrogen, H ...	43·9	35·2 to 40·8	42·0 to 48·1	27·0 to 46·0	40·1
Marsh gas, CH_4 ...	26·6	18·6 ,, 19·0	18·4 ,, 20·3	14·0 ,, 29·0	22·8
Carbon monoxide, CO	7·0	12·6 ,, 13·4	10·2 ,, 11·8	4·0 ,, 5·2	9·0
Heavy hydrocarbon gases ..	3·0	0·4 ,, 1·4	1·8 ,, 2·6	1·0 ,, 2·0	1·6
Carbon dioxide, CO_2	3·5	2·3 ,, 4·0	4·9 ,, 5·3	4·2 ,, 5·0	5·7
Oxygen, O ...	0·3	1·0 ,, 1·2	0·2 ,, 0·4	0·3 ,, 1·2	0·6
Nitrogen, N ...	15·4	26·3 ,, 26·6	15·9 ,, 18·7	20·0 ,, 40·0	20·2
Sulphur, S ...	—	—	—	0·20	—
Calorific value in British thermal units	480 to 560	320 to 412	412	340 to 360	390

The amount of power to be derived from a battery of 80 ovens of a modern type, coking a charge of 7 tons in 32 hours, using coal of a medium percentage of volatile matter, giving off about 7,000 cubic feet of gas per ton per hour, or in all 122,500 cubic feet per hour, would, therefore, be as follows:—If the ovens used 70 per cent. of the gases for heating the flues, then there should remain about 36,000 cubic feet for power, and, taking a consumption of 25 cubic feet per indicated horsepower, about 1,500 indicated horsepower should be available, or nearly 20 indicated horsepower per oven. This amount varies, of course, with the coal and type of oven, and the writer knows of cases where the power was nearly 30 indicated horsepower per oven.

The Cleaning of Coke-oven Gas.—The purification of the gases is of primary importance, and nothing should be neglected to arrive at the highest degree of purity. Most of the early failures in blast-furnace and coke-oven gas-plants were traceable to imperfect cleaning: perfect cleaning not being thought necessary. Tar and ammonia are condensed with comparative ease and so too the naphthaline (benzol) and cyanogen; but the dust in connection with the remaining quantities of tar should be most carefully removed.

After varied and lengthy experiments, the writer has come to the conclusion that the correct method is to purify all the gases from dust, including the gases used in the gas-engines,

and the gases used for heating the oven-flues and the boilers. The higher calorific value of the purified gas ensures higher temperature in the flues and better coking, and also saves gas. The purified gas does not cover the oven-flues and boilers with a coating that demands repeated cleaning. Another condition is the elimination of water-vapour. The gases from the ovens contain from 5 to 15 per cent. of water-vapour, especially if the charge consists of washed coal. This water has the effect of rendering the gas difficult to burn. At the same time, the temperature must be lowered from 280° to about 60° Fahr. Water-sprayed fans and quickly-revolving washers on the Theissen principle are too expensive, and require too much power to drive them; and, moreover, the water is brought into contact with the hot gases, and charges the latter with a further quantity of water-vapour.

A complete revolution in these methods was produced by the introduction of the slowly revolving washer. The apparatus is giving most excellent results at blast-furnace gas-plants, and the writer is of opinion (based on experiments) that its introduction into all coke-oven plants is highly desirable, even if no gas-engines are installed. It is cheap, highly efficient, and requires much less water than other appliances. The gases are cooled from 550° to 400° down to 86° Fahr. in certain cases, at the same time losing their water-vapour by condensation. The main purpose is, of course, the elimination of dust, and consequent better utilization of the ovens and boilers.

The further gas-cleaning plant depends on the particular methods of extracting the bye-products used at each coking-plant; and, therefore, no general rule can be laid down for the apparatus required.

The tar and ammonia are extracted in a row of condensers using water and air as a cooling medium; and, afterwards, in washers and scrubbers of different construction. The washers and scrubbers may be combined with dust-extracting and additional cleaning plant. The extraction of tar is, of course, dependent on the state in which the tar is present in the gases (whether in fine spray or otherwise), and this largely depends on the cooling arrangements. The danger of leaving tar in the gases cannot be exaggerated; and sticky valves, pre-ignition and sooty cylinders are such highly undesirable features that it is easy to understand

the importance of evading them. To do this at once, after the gases leave the ovens, and at the same time to do away with the presence of steam due to the moisture present in the coal and to the cooling water, is the object of the rotary washer.

As rotary washers are likely to supersede all the present arrangements for cooling and purifying coke-oven and blast-furnace gases, a short description of the Bian washer may be of interest. In a metal cylindrical shell, a number of wire-gauze discs revolve slowly on a horizontal axle, immersed up to their centre in flowing water. The hot gases enter at the front side and are confronted with the wire-gauze discs, containing thin films of water in the meshes; these water-films are evaporated at once, and the gases give off some of their latent heat. This process is repeated until the gases are not hot enough to evaporate more water, and then the films act as condensers and condense the vapour present in the gas. At the same time, the greater part of the impurities are precipitated, and the gases are cooled and ready for further cleaning. The gases even become richer, as part of the carbon dioxide is dissolved in the water, while the greater part of the water-vapour, present in the gas as it comes from the ovens, is eliminated. The fans used for the additional cleaning may therefore be much smaller, and absorb less power than when used on the hot gases.

Bian washers are now installed in various works in Germany and Belgium, etc., and have been entirely successful, using about 40 horsepower, including the driving of the ventilator or fan and cleaning 40,000 cubic feet of gases per minute in one apparatus. For a battery of, say, 50 modern retort-ovens, this would mean about 15 horsepower. The cooling reached in most installations is up to 60° Fahr. At this temperature it is comparatively easy to extract the remaining tar-spray before the gases enter the ammonia and benzol separator: a simple coke-scrubber being perfectly sufficient.

Tar.—The essential conditions for extracting the tar are gradual and efficient cooling, combined with some kind of wet and dry cleaning.

The initial cooling and dry cleaning in air-coolers or condensers is generally considered to render the wet cleaning by means of a Theissen or, better still, a Bian or Holmes washer,

more effective. They are cheap, and require no power or supervision, as they simply consist of a number of U tubes standing on a horizontal receiver, half filled with tar. Between the two legs of each tube is a plate with its end in the tar, so as to force the gases through the tubes; sometimes the receiver is divided in two, and the gases only pass through one pair of tubes. The latter arrangement provides for the passage of more gas in the same apparatus. The coolers reduce the temperature of the gases from about 550° Fahr. to 170° Fahr., and cost about 3s. per square foot of cooling surface. They may be arranged in parallel or in series, and any combination to suit requirements can easily be effected.

The most up-to-date plants have a revolving gas-washer, of any of the abovementioned makes, directly connected to the air-cooling plant; the temperature is further reduced from 170° down to 70° or 60° Fahr. In addition to and in consequence of the cooling effect, the tar and dust are for the greater part eliminated.

Directly after the washer come gas-fans, Root blowers, exhausters or turbine-exhausters, which give the necessary velocity through the cleaning and bye-product plant. The temperature of the gases being much lower, these fans or ventilators can be used of much smaller dimensions than formerly, when they were installed directly after the air-cooling plant.

FIG. 4.—PELOUZE-ADOUIN TAR-SEPARATOR.

Bye-product Plant.—The gases now enter the bye-product plant, which comprizes: (1) A tar-separator, of some kind; (2) an ammonia-washer; (3) a benzol-washer; (4) a cyanogen-washer; (5) a hydrogen-sulphide washer; and the necessary stills, separators and tanks for the manufacture of sulphate of ammonia, commercial tar and pitch, light oils, benzine, etc.

(1) The tar-separator generally consists of one or more coke or sawdust scrubbers, but in the older plants a Pelouze-Adouin (Fig. 4) or other special tar-separator is used. At present, the latest practise is to use the Bian or Theissen washer, with tar as a washing and cooling medium, to remove the last traces of sooty tar.

FIG. 5.—HOLMES ROTATING GAS-WASHER.

(2) The ammonia-washer either consists of one of the many scrubbers (of which the Zschocke scrubber is far the best) or of a rotary washer of the Holmes or Zschocke type. Zschocke scrubbers require about 2 gallons of cooling water per 1,000 cubic feet of gases, and leave only about 5 grains of ammonia (NH_3) per 1,000 cubic feet of cleaned gas. The Holmes rotating-washer (Fig. 5) is one of the slowly-revolving type (1 revolution per minute), and consists of a cylindrical drum with brushes revolving on a horizontal axle. The Zschocke washer has a revolving part, consisting of wooden balls with holes fixed in a

disc-holder. Both types have several compartments connected by tubes, and water is supplied in a direction opposed to the flow of the gases. Owing to the slow rotating movement, the power-consumption is very small. These appliances extract nearly all the ammonia, leaving only 2½ grains per 1,000 cubic feet. The washing-water may be either pure water or liquor, and may be used over and over again, until a solution of sufficient strength is obtained.

(3) The benzol or naphthalene is extracted by the same class of apparatus as the ammonia, the washing medium being tar-oil.

(4) The cleansing for sulphur and cyanogen is not generally considered necessary. Most of the German coke-works, however, have adopted some sort of cleaning plant, and the writer certainly agrees with this policy. The valves, and especially the spindles, may or may not be attacked by the acids which are formed by the oxidation of the hydrogen sulphide in the cylinders. The protection, however, of the costly gas-engine plant is of such primary importance, and, if any doubt exists, the removal of both sulphur and cyanogen should be insisted upon by the makers of the gas-engine, as cyanogen attacks the pipes and cylinders, and reduces the heating value of the gas. Of course, much depends on the composition of the coal and the amount of sulphur contained therein, and it must not be forgotten that most of the sulphur remains in the coke.

Several types of dry scrubbers, sometimes in combination with a revolving washer, have been used for this purpose in different German works. These appliances are rather costly and create a certain nuisance, as the active matter (in this case iron-ore and sawdust or wood-wool) has to be renewed very often. It is, however, possible to use it over and over again (ten times) by regenerating it in the open air. Moreover, the saturated iron-ore is a marketable product, as it can be used for the production of cyanogen.

Dry scrubbers have, however, another duty to perform: the final removal of the last traces of tar and water, and the tar-oils used in the benzine-washers.

In works where sulphur-troubles are not to be feared, one may see dry scrubbers being used for a final cleaning, containing layers of iron-ore and of wood-wool. They must be cleaned every 8 or 10 weeks. Recently slag-wool has been used, with satisfactory results, as a scrubbing agent.

The most up-to-date and cheapest sulphur-extracting plant is erected at the Mathias Stinnes colliery. A revolving cleaner of the Bian type is used to extract the sulphur and cyanogen by mixing fine hydroxide of iron in the water, whereby sulphide of iron is formed, and it may again be regenerated by blowing air under pressure through the cleaner. It is also a marketable commodity which can be sold to sulphuric-acid manufacturers.

It is not intended to describe the various stills and tank arrangement used for the distillation and the manufacture of saleable bye-products, such as tar, pitch, sulphate of ammonia, benzol, tar-oils, etc.

The control and constant pressure of the gases may be ensured, by a speed-regulation apparatus placed in front of the fans or turbine-exhausters. It is an equalizer, regulating the equilibrium of the gases between the exhaust and pressure sides, by means of a diving-bell balanced by a counter-weight. The movements of the bell are communicated to a double-acting valve, which establishes communication between the exhaust and pressure sides.

In order to ensure the thorough mixture of the gases from the ovens in different stages of the coking process, a gas-holder of reasonable dimensions is of great advantage. An hour's supply should be provided for, with about 20 cubic feet capacity per horsepower installed.

Gas-engines.—The scope of this paper does not admit of a complete treatment of the coke-oven gas-engine and the different types and makers. The large gas-engine industry is still in its infancy, to use a commonplace expression, but although there are now several good systems, and each system has its particular advantage, it is the expert's work to distinguish and to adopt the correct engine in each particular case, depending on the gases available, their degree of purity, and many other particulars (Table II.).

The principal theoretical grouping consists in dividing gas-engines into four-cycle and two-cycle engines. The particular features of each kind are so well known that it should be sufficient to enumerate shortly the advantages and drawbacks of each type, at the same time giving some particulars of the different makes. The large gas-engine is far more difficult to

construct than a large steam-engine, and the technical difficulties may be said to increase with the size. The correct choice of the materials to be used, and the particular construction of the working parts owing to the enormous stresses and temperatures, are difficult problems, which it took reputed makers many years to solve. At present, therefore, only first-class makers with well-established records of engines of the same size should be considered.

TABLE II.—LIST OF RECENT INSTALLATIONS OF COKE-OVEN GAS-ENGINES.

Name of Works.	Type of Gas-engine.	Total Power Employed.	Number of Gas-engines.	Capacity of each Gas-engine.
		Horsepower		Horsepower.
Withomitz Colliery ...	Berlin-Anhalt: four-cycle, with four cylinders	900	3	300
Graf-Lärisch Colliery: Karwin	Berlin-Marienfelde: four-cylinders, single-acting	700	1	700
Carolinen Colliery ..	Cockerill: four-cycle, single-acting	250	1	250
Yorkshire Iron and Coal Company, Tingly	Cockerill: four-cycle	500	2	250
Gross Wolkte Colliery ...	Koerting: two-cycle, with two cylinders	500	1	500
Julien Iron-works ...	,, ,,	1,200	4	300
Messel Colliery	,, ,,	1,000	2	500
Neunkirchen Coke-works: Stumm	Nürnberg: single-acting	200	1	200
Burbach Iron-works and Coke-works	Nürnberg: double-acting	1,200	1	1,200
Consolidation Colliery ...	,, ,,	160	1	160
,, ,, ...	,, ,,	1,360	2	680
Constantin Colliery: Bochum	,, ,,	1,200	1	1,200
Eschweil Colliery ...	,, ,,	1,000	2	500
,, ,, ...	,, ,,	1,100	1	1,100
Gelsenkirchen Colliery ...	,, ,,	500	1	500
Lothring Colliery ...	,, ,,	350	1	350
Minister Stein Colliery ...	,, ,,	550	1	550
Shamrock Colliery ...	,, ,,	800	1	800
Stumm Colliery	,, ,,	1,000	1	1,000
Anna Colliery	Oechelhauser: two-cycle, with two cylinders	550	1	550
Borsig	,, ,,	600	1	600
Cargo Fleet Iron-works ...	Premier	1,000	2	500

The ordinary four-cycle or Otto engine has the advantages of simplicity and high efficiency, and it occupies comparatively small floor-space; it has, of course, only one impulse in four strokes, and is, therefore, not very suitable to be coupled to three-phase generators, which have to work in parallel.

In order to reduce the size of single-cylinder engines, engines of over 200 horsepower are built, with two or four cylinders, either side by side or in tandem. The latter arrangement has the advantage of less loss through friction, as there is only half the bearing-surface and one flywheel and crank. Large engines, of 1,200 horsepower and more, are usually built with four cylinders, arranged as a double-tandem engine. Although a step in the right direction, the two and four-cylindered single-acting engine still has several drawbacks. The engine is bulky, and therefore heavy and costly; it shows an increased oil-consumption, and therefore high-running costs: and it requires considerable floor-space.

FIG. 6.—NÜRNBERG SINGLE-CYLINDER DOUBLE-ACTING COKE-OVEN GAS-ENGINE, OF 560 HORSEPOWER, AT GELSENKIRCHEN COLLIERY.

In order to combine the advantages of the multi-cylinder engine (regularity, smaller cylinders, and all round less bulky dimensions), the double-acting engine was brought out, thus again following steam-engine practice. In this way, the full advantages of the two-cycle engine are obtained, while retaining the simple construction of the four-cycle engine. The best-known engine of this type gives about double the power for the

same dimensions. It has one small disadvantage, the use of stuffing-boxes, which, however, it has in common with the tandem-engine.

The best known large four-cycle gas-engines built to use coke-oven gas are the Nürnberg, the Deutz, the Koerting, the Berlin-Anhalt, the Danek, and the Cockerill. Each of these wellknown engines have, of course, their particular advantages, though the Nürnberg engine has been perhaps the most popular. The very high efficiency of this engine is due to the double acting, two

FIG. 7.—NÜRNBERG TWO-CYLINDER DOUBLE-ACTING COKE-OVEN GAS-ENGINE, OF 1,000 HORSEPOWER, AT STUMM COLLIERY.

or four-cylindered tandem arrangement, giving the advantages of great regularity and reasonable dimensions of the two-cycle engine, while retaining in full the simplicity and high thermal efficiency (28 to 39 per cent.) of the four-cycle engine. In addition, the engine is extremely easy to dismantle, in order to clean the valves and cylinders, an advantage which will be appreciated at coke-oven and blast-furnace works where the gases for some reason or another are not sufficiently clean and

free from tar or dust. Figs. 6, 7 and 8 show recent installations at coke-oven works abroad where Nürnberg gas-engines of large capacity have been installed.

A short description of a typical large coke-oven gas-engine of the Nürnberg type may be of interest. The cast-steel bed-plate extends the full length of the engine, it acts as a guide for the crosshead, carries the main bearings, and it acts as an oil-sink for the oil-lubrication of the cranks. The action of the gas-engine being downward, there is only one guide-

FIG. 8.—NÜRNBERG TWO-CYLINDER DOUBLE-ACTING COKE-OVEN GAS-ENGINE, OF 1,100 HORSEPOWER, AT ESCHWEIL COLLIERY.

lining. The symmetrically-shaped cylinders are made of cast-iron, which material responds better to the variations due to excessive heat. The cylinders are water-jacketted all round, including the ends and heads. The valve-chests, where the gas and air are mixed, are screwed to the cylinders; they are also water-cooled. A distance-piece carries the guide between the cylinders The water-cooled pistons are carried on specially hollow cast-steel rods, which also act as cooling-water supply-pipes. They are short, and are fitted with cast-iron rings. The

crossheads are made of nickel-steel, and slide on the white-metal lining of the guides. The construction of the connecting-rod renders it quite possible to extract the piston without dismantling the crosshead and guides. The crank-shaft, made of Siemens-Martin steel, revolves in two bearings lined with white-metal. Forced lubrication is supplied by a small oil-pump, and there is a separate one for each stuffing-box. The inlet-valves have an independent circular slide-valve fixed to the stem; they are actuated by roller-path levers, eccentrics and ratchet-movements fixed on one shaft. The governor acts directly on the stroke of the inlet-valves, and is driven by the valve-gear shaft. The air and gas are mixed in the double gas-valve, and enter the cylinder through the inlet-valve. The exhaust-valve, which is pressed on its seat by the explosion, is water-cooled, as is also the exhaust-valve chest. The cooling-water is further compressed by a small pump, and flows through the different water-jackets into a common drain-pipe, which conveys it to the cooling-tower or other water-saving apparatus. The quantity of water required is about 6 gallons at 60° Fahr. per brake-horsepower-hour, and if cooling-towers are used the water required to make up the loss is about 0·4 gallon per brake-horsepower-hour.

The two-cycle engine is represented by the Cockerill, the Koerting, and the Oechelhauser engines, which have been extensively used at blast-furnace and coke-oven works in Germany. Their chief advantage is the regularity which is ensured by having one impulse every two strokes, instead of every four strokes. The double-acting, two-cycle Koerting engine, as well as all other Koerting engines, is provided with a special mixing-valve, regulating the simultaneous passage of the air and gas before admission into the cylinder. The automatic valves are lifted by the suction only, falling back by their own weight as soon as the inlet-valve closes through compression. The inlet-valves, operated by cams, are situated at each end of the cylinder, while the exhaust-ports are placed in the centre. The gas and air are supplied by separate pumps, which first deliver pure air and then a mixture of uniform composition, the quantity of which regulates the power of the engine. The pressure exerted by the pumps is about 15 pounds per square inch (Figs. 9 and 10).

The Oechelhauser engine is in so far the simplest, as there are no valves, and the mixture introduced by the pumps is compressed between two pistons in one cylinder. The gas and air are supplied by one pump, in line with the engine, and actuated by the back-piston rod. The pistons, themselves, form slide-valves, and the engine is single-acting. Notwithstanding a certain complication due to the various connecting-rods and the use of three

Fig. 9.—Four Koerting Two-cycle, Single-cylinder Double-acting Coke-oven Gas-engines, of 300 Horsepower, at Julien Iron-works.

cranks, this arrangement ensures simplicity and a perfect balancing of the working parts, and especially of the crank-shaft, neutralizing the reactions of the bearings. The disadvantages are the great length (although the pump can be arranged under the engine) and the great weight and dimensions of the single-acting type, and a somewhat lower efficiency, which the engine has in common with all two-cycle engines fitted with separate pumps. Also, it appears to the writer that the small

pump-cylinders and valves are not exactly the place for the possible accumulations of dust which take place in the cylinders of the four-cycle engine. The net efficiency of the two-cycle engine is about 75 to 80 per cent. while 90 to 92 per cent. is reached by the four-cycle engine.

In double-acting four-cycle engines, of which the Nürnberg is the best type, the thermal efficiency varies from 28 to 30

FIG. 10.—KOERTING TWO-CYCLE. SINGLE-CYLINDER DOUBLE-ACTING COKE-OVEN GAS-ENGINE, OF 500 HORSEPOWER, AT MESSEL COLLIERY.

per cent. of effective work, and about 20 cubic feet of coke-oven gas per horsepower. The weight is now about 200 pounds per horsepower. For use with coke-oven gases, where the efficiency is more important than with blast-furnace gases, four-cycle engines of the Nürnberg type are decidedly to be recommended.

Mr. GERALD H. J. HOOGHWINKEL said that he advocated the erection of coke-ovens or gas-producers at every colliery, not because the owners wanted to make coke; but in order to get rid of an enormous amount of dirt and waste, which should be coked, and the coke-oven plant should be used as a gas-producer. For, after all, a coke-oven plant was in a way a huge gas-producing plant, and the best way of getting rid of this waste-material was to put it into gas-producers or coke-ovens, instead of wasting and storing it at the colliery. If coke-ovens were used as gas-producers sufficient gas would be made to work all the plant of the colliery with it. As a secondary product, there would be the coke, which at some collieries would be good furnace-coke; and at others, it would be sold for household purposes, etc. The gas would be the principal product, and the coke should be considered as a bye-product. In some towns in the United States, coke-ovens had been erected instead of ordinary gas-retorts, and the gas was sold for lighting purposes only.

The CHAIRMAN (Mr. Henry Hall) said that the writer implied that there should be coke-ovens at every colliery, and that the gas should be drawn from the coke-ovens and sent to the boilers or gas-engines direct. He thought that it would be difficult to establish coke-ovens at all collieries, because there were really very few collieries producing coal that would make coke at all. There were very few coke-ovens in the Lancashire district: the reason being that the coal is not suitable. A long time ago, when he (Mr. Hall) was manager of a colliery, the idea was mooted that the gases from the coke-ovens should be utilized; and one or two schemes were tried of collecting some of the gases and applying them under steam-boilers. But the result always seemed to be that, so soon as the ovens were modified in this way, complaints came from the iron-works that the coke was inferior to that which had been sent previously, and ultimately it really meant that if the gas was utilized the general value of the coke was reduced. That was an important point in the proposed scheme; and, in fact, it was the real reason why the utilization of these gases had not become more general. Coke for sale must be of good quality, and the colliery-owner could not afford to injure it in any way. He (Mr. H. Hall) had pleasure in moving a vote of thanks to Mr. Hooghwinkel for his paper.

Mr. W. H. Johnson, in seconding the proposal, remarked that no doubt gas-engines had a great future before them, and everything that would tend to bring that future nearer would be acceptable to the members.

The motion was carried unanimously.

Mr. George Elce described the way in which the coke-and-gas question was dealt with at the colliery with which he was connected. As the gas obtained was not sufficient for lighting purposes, it was used for heating the ovens themselves, and after the gas had been burned in flues round the ovens, it was passed under the boilers in a somewhat old-fashioned way. The gas produced at the coke-ovens would never be able to run an electric plant, but it sufficed to run the bye-product pumps. He thought that the prejudice against retort-coke, mentioned by the chairman, because the gas had been collected from it, had been overcome and did not now exist.

Mr. A. Dury Mitton agreed with Mr. Hall that there were many coal-seams in Lancashire quite unfit for coking. He had experimented on the coal from a large number of them and found that the density, as also the percentage of volatile matter or of ash, was the main cause. He did not think that Mr. Hooghwinkel's suggestion was practicable, namely, to erect coke-ovens simply for the bye-products, and to leave the coke as a waste-product, when unsaleable. The price and market for small coal for the mills in Lancashire was a feature in coke-making, which had to be carefully considered in comparison with other coal-fields. He thought that, if proper care was taken and the latest appliances were used, retort-oven coke would hold its own in any market against the product obtained from the bee-hive coke-oven.

Mr. R. L. Gamlen remarked that a Koerting gas-engine of 2,000 horsepower covered a space 55 feet 9 inches long and 50 feet broad, while a Curtis turbine, of the same capacity, was only 10 feet square. The gas-engine covered a floor-space of 2,700 square feet, whereas a steam-turbine of the same horsepower covered only 100 square feet; and, in the same way, a gas-engine of the above-mentioned size weighed 340 tons against 35 tons in the case of a turbine, or practically ten times as much. He thought that the cost of the buildings and founda-

tions to cover and support the various types of engines must be, of necessity, highly in favour of the smaller plant. Before the erection of the plant of the Lancashire Power Company was commenced he spent some time in journeying through Great Britain examining many cases of driving by gas-engines, and he came to the conclusion that, at present, at any rate, there was not sufficient reliable experience to warrant the adoption of this class of drive; and time had only confirmed his opinion on that point.

He knew of an order for two gas-engines of 700 horsepower that was given nearly three years ago, and he believed that they were just starting to turn round. The delay in getting to work had been entirely due to the unsatisfactory performance of the plant and the overcoming of experimental difficulties. If it had been necessary to spend all this time in experimentation in order to bring a small plant, with engines of 700 horsepower, to a fit state of work, it was conceivable that as many more years might have to pass before a plant of 2,000 horsepower could be made to work satisfactorily.

There was now an extremely satisfactory method of disposing of very dirty coal, other than by burning it in a producer, namely, by dust-firing. There had been in the past great difficulty in utilizing coal-dust as fuel, as the combustion-chamber had invariably melted away in the very fierce heat. Now, however, carborundum-lined fire-bricks were used, which would stand an enormous temperature. In one case, where the calorific value of the fuel was about 10,000 British thermal units, the percentage of carbon dioxide was uniformly as high as 15, shewing very perfect combustion. The bye-product was liquid slag and dust, both of which were far more easily handled than ordinary slag from a furnace of whatever type.

Mr. W. H. Coleman described a method by which coke-oven gas could be cleansed from impurities, and said any plan that tended to economy in the use of coal was worthy of the attention of the members.

Mr. Gerald H. J. Hooghwinkel stated that nearly all coal could be made into coke, if it was sufficiently mixed in different quantities and qualities, crushed and the charge compressed. The only economical and profitable way of dealing with the

rubbish was to put it into coke-ovens or into gas-producers. Burning it under boilers was a most wasteful process, unless it was properly treated by washing or pulverizing. If there was no demand for coke, the use of gas-producers was preferable; but, if there were a sufficient demand for coke, coke-ovens should be erected. It was an error to suppose that the quality of the coke was injured if the gas was extracted from it. He did not think that the extraction of the bye-products did any harm to the coke; and, on the contrary, he believed that the coke was better for their extraction. The slack and waste, valued at 3s. to 4s. per ton in Lancashire, could be utilized far better in the production of coke and electric power.

The steam-turbine was no doubt the ideal steam-engine, and the Curtis turbines at the power-station of the Lancashire Power Company required very little ground-space. The large area of 2,700 square feet was mentioned as being required for a gas-engine of 1,000 horsepower; but, as a matter of fact, a Nürnberg gas-engine of 1,000 horsepower only required an area of 400 square feet.

The advantage of the introduction of the flexible electric agent between the gas-engine and the mining plant, instead of direct driving by the gas-engine, was too evident to be seriously disputed.

THE INSTITUTION OF MINING ENGINEERS.

SIXTEENTH ANNUAL GENERAL MEETING,

HELD IN THE TOWN HALL, MANCHESTER, SEPTEMBER 13TH, 1905.

MR. H. C. PEAKE, PAST-PRESIDENT AND CHAIRMAN OF COUNCIL, IN THE CHAIR.

ELECTION OF OFFICERS, 1905-1906.

The SECRETARY announced the election of officers for the ensuing year by the Council as follows:—

PRESIDENT:
SIR LEES KNOWLES, BART.

VICE-PRESIDENTS:

MR. WILLIAM ARMSTRONG.	MR. A. H. HEATH.	MR. R. T. MOORE.
MR. T. W. BENSON.	MR. W. B. M. JACKSON.	MR. H. B. NASH.
MR. H. BRAMALL.	MR. GEORGE MAY.	MR. W. G. PHILLIPS.
MR. JOHN DAGLISH.	MR. R. MCLAREN.	MR. J. G. WEEKS.
MR. J. T. FORGIE.	MR. T. W. H. MITCHELL.	MR. R. S. WILLIAMSON.

AUDITORS:
MESSRS. JOHN G. BENSON AND SONS, Newcastle-upon-Tyne.

TREASURERS:
MESSRS. LAMBTON & COMPANY, The Bank, Newcastle-upon-Tyne.

Mr. JOHN GERRARD moved a vote of thanks to the retiring Vice-Presidents, Councillors and officers for their services during the past year.

Mr. S. F. WALKER seconded the resolution, which was cordially approved.

The SECRETARY read the Annual Report of the Council as follows:—

SIXTEENTH ANNUAL REPORT OF THE COUNCIL.

It is the painful duty of the Council to report the death of their esteemed President and colleague, Sir Lowthian Bell, Bart., one of the founders of the Institution, who presided at the initial meeting held in London on June 6th, 1888. They have conveyed to Sir Hugh Bell, Bart., and the family of Sir Lowthian Bell an expression of their deep regret at the irreparable loss which they have sustained, and of their sincere sympathy with them in their bereavement. It is impossible to estimate the value of the services that Sir Lowthian Bell rendered to The Institution of Mining Engineers, in promoting its objects and in devoting his time and energies to its advancement.

The following table exhibits the progress of the membership since the formation of the Institution in 1889:—

Year ending July 31st.	No. of Honorary Members.	No. of Members.	No. of Non-federated.	Totals.
1890	0	1,189	50	1,239
1891	0	1,187	9	1,196
1892	14	1,401	19	1,434
1893	14	1,519	19	1,552
1894	13	2,055	123	2,191
1895	13	2,197	109	2,319
1896	13	2,288	81	2,382
1897	13	2,434	60	2,507
1898	13	2,449	47	2,509
1899	15	2,430	41	2,486
1900	15	2,432	35	2,482
1901	15	2,509	30	2,554
1902	15	2,556	30	2,601
1903	17	2,645	26	2,688
1904	17	2,742	22	2,781
1905	16	2,944	74	3,034

The societies constituting The Institution of Mining Engineers have been increased, during the year just ended, to seven, by the adhesion of the Manchester Geological and Mining Society, this society having joined the Institution from August 1st, 1904. The Institution now comprizes the Manchester Geological and Mining Society; the Midland Counties Institution of Engineers;

the Midland Institute of Mining, Civil and Mechanical Engineers; the Mining Institute of Scotland; the North of England Institute of Mining and Mechanical Engineers; the North Staffordshire Institute of Mining and Mechanical Engineers; and the South Staffordshire and Warwickshire Institute of Mining Engineers.

The Annual General Meeting of the Institution was held in Birmingham, on September 14th, 15th and 16th, 1904. The London Meeting was held on June 1st, 2nd and 3rd, 1905. Both of these meetings secured the attendance of a considerable number of members, and the papers communicated were of an interesting character. The thanks of the Institution have been sent to the owners of collieries, works, etc., which were thrown open to the members attending these meetings.

Prizes have been awarded to the writers of the following papers, which are printed in the *Transactions* (vols. xxvi. and xxvii.):—

"The Occurrence, Mode of Working, and Treatment of the Ironstones found in the North Staffordshire Coal-field." By Mr. John Cadman.

"The Action, Influence and Control of the Roof in Longwall Working." By Mr. H. W. G. Halbaum, M.Inst.M.E.

"Underground Temperatures, especially in Coal-mines." By Prof. Hans Hoefer.

"The Dynamics of the Winding-engine." By Mr. S. L. Thacker, M.Inst. M.E.

"Electric Coal-cutting." By Mr. W. Walker.

"The Re-tubbing of the Middle Pit, Murton Colliery, 1903." By Mr. W. O. Wood, M.Inst.M.E.

Addresses have been delivered during the year by Mr. John Gerrard, President of the Manchester Geological and Mining Society; by Mr. T. W. H. Mitchell, President of the Midland Institute of Mining, Civil and Mechanical Engineers; by Dr. Robert Thomas Moore, President of the Mining Institute of Scotland; by Mr. A. H. Heath, President of the North Staffordshire Institute of Mining and Mechanical Engineers; and by Prof. R. A. S. Redmayne, President of the South Staffordshire and Warwickshire Institute of Mining Engineers.

The papers comprized in the *Transactions* during the past year have been of an interesting and varied character, and the high standard of the *Transactions* has been well maintained.

The papers on geology include the following:—

"Notes on the Crow's Nest Coal-field, British Columbia." By Mr. James Ashworth.

"The Hunter V. Mine, British Columbia." By Mr. James Ashworth.

"*Prestwichia anthrax* and *Belinurus lunatus* from Sparth Bottoms, Rochdale." By Mr. Walter Baldwin.

"Sparth Bottoms Quarry, Rochdale." By Mr. Walter Baldwin.

"A Section of the Glacial Deposits met with in the Construction of the New Docks at Salford." By Prof. W. Boyd Dawkins.

"The Permian and Carboniferous Rocks in a Section in High Street, Chorlton-on-Medlock, Manchester." By Prof. W. Boyd Dawkins.

"Note on a Natural Paraffin found in the Ladysmith Pit, Whitehaven Collieries." By Mr. R. Dodds.

"The Cullinan Diamond." By Dr. G. A. F. Molengraaff.

"The Northern Portion of the Bristol Coal-field." By Mr. J. T. Onions.

"Coal-mining in Borneo." By Mr. James Roden.

"The Coal-fields of Cape Colony." By Mr. Archibald Russell.

"The Geology of Chunies Poort, Transvaal." By Mr. Arthur Robert Sawyer.

"Gold-mining in Southern Rhodesia." By Mr. Thomas Warth.

"Notes on Coal in the Transvaal." By Mr. John J. Whitehead.

Mining engineering has been the subject of the following papers:—

"Goaf-blasts in Mines in the Giridih Coal-field, Bengal, India." By Mr. Thomas Adamson.

"Systematic Timbering at Emley Moor Collieries." By Mr. Hiram Baddiley.

"The Action, Influence and Control of the Roof in Longwall Working." By Mr. J. T. Beard.

"A Method of Packing Excavations in Coal-seams by Means of Water." By Mr. E. O. Forster Brown.

"Mountain Tunnelling." By Mr. Joseph Dickinson.

"Tapping and Running-off a Head of Water from a Shaft." By Mr. John Fox.

"Problems of Working Thick Coal in Deep Mines." By Mr. Laurence Holland.

"Coal-mining in Asturias, Spain." By Prof. Henry Louis.

"An Inburst of Waste-water at Wallyford Colliery." By Dr. Robert Thomas Moore.

"The Use of Cement-concrete in the Working of Thick Coal-seams." By Mr. Joseph Hippolyte Piffaut.

"The Action, Influence and Control of the Roof in Longwall Working." By Mr. Edward Heton Roberton.

"Coal-mining in Borneo." By Mr. James Roden.

"Notes on the Principal Gold-mining Districts and Mines of Western Australia." By Mr. W. T. Saunders.

"Description of Houldsworth Colliery, Dalmellington." By Mr. William Smith.

"The Bengal Coal-fields, and some Methods of Pillar-working in Bengal, India." By Mr. George A. Stonier.

"Gold-mining in Southern Rhodesia." By Mr. Thomas Warth.

"Notes on Coal in the Transvaal." By Mr. John J. Whitehead.

The following papers have been contributed on mechanical engineering:—

"The Hunter V. Mine, British Columbia." By Mr. James Ashworth.

"The Automatic Prevention of Overwinding of Hoisting, Winding and Haulage-engines or Motors." By Mr. J. S. Barnes.

"Safety-catch for Cages." By Mr. Joseph Clegg.

"Winding of Minerals from Inclined Shafts." By Mr. Robert Crawford.

"The Electrical Driving of Winding-gears: Supplementary Note." By Mr. F. Hird.

"Electric Pumping at Collieries." By Mr. Gerald H. J. Hooghwinkel.

"The Compound Winding-engine at Lumpsey Mine." By Mr. Matthew Robson Kirby.

"Electric Winding-engines at the Exhibition of the North of France, Arras, Pas-de-Calais." By Mr. Ed. Lozé.

"Pneumatic Coal-boring Machines and Tools." By Mr. W. Lynch.

"Notes on Capels for Winding-ropes." By Mr. T. W. H. Mitchell.

"The Problem of Dynamic Balance." By Mr. Edward Heton Robertson.

"The Circulation of Water in Steam-boilers." By Mr. Arthur Ross.

"Notes on the Principal Gold-mining Districts and Mines of Western Australia." By Mr. W. T. Saunders.

"A Colliery Plant: its Economy and Waste." By Mr. A. J. Tonge.

"Fire in a Lanarkshire Colliery, and Description of a Condenser used thereat." By Mr. James C. Weir.

"A Safety-brake for Hand-cranes." By Mr. G. J. Williams.

The applications of electricity have been discussed in the following papers:—

"The Automatic Prevention of Overwinding of Hoisting, Winding and Haulage-engines or Motors." By Mr. J. S. Barnes.

"Notes on the Application of Electric Power at Mines in Germany." By Mr. E. O. Forster Brown.

"Notes and Considerations on Systems having Work of an Intermittent and Irregular Character to Perform: Methods of Load-compensation." By Mr. Maurice Georgi.

"The Electrical Driving of Winding-gears: Supplementary Note." By Mr. F. Hird.

"An Outbreak of Fire, and its Cause, at Littleburn Colliery." By Mr. M. F. Holliday.

"Electric Pumping at Collieries." By Mr. Gerald H. J. Hooghwinkel.

"Electric Winding-engines at the Exhibition of the North of France, Arras, Pas-de-Calais." By Mr. Ed. Lozé.

"A Colliery Plant: its Economy and Waste." By Mr. A. J. Tonge.

"An Electric Indicating Two-wire Signal." By Mr. J. Willis.

"A Fatality caused by Low-pressure Electric Current in a Lancashire Colliery." By Mr. George H. Winstanley.

Mine-surveying instruments have been discussed in the following paper:—

"Mine-surveying Instruments: Part II." By Mr. Dunbar D. Scott.

The education of mining engineers has been discussed in the following papers:—

"The Education of Mining Engineers in the United States." By Prof. Howard Eckfeldt.

"An Outline of Mining Education in New Zealand." By Prof. James Park.

"The Mining Department of the University of Birmingham." By Prof. R. A. S. Redmayne.

"The Development of Higher Education in North Staffordshire." By Prof. Thomas Turner.

Ankylostomiasis has been discussed in the following papers:—

"The Miners' Worm-disease as seen in Westphalian and Hungarian Collieries." By Dr. Thomas Oliver.

"The Effect of the Watering of Coal-mines on the Spread of Ankylostomiasis." By Mr. Jonathan Wroe.

Dust and its treatment has been the subject of the following papers:—

"Observations on Water-sprayed or Damped Air in Coal-mines." By Mr. James Ashworth.

"Outbursts of Gas and Coal at the Morrissey Collieries, British Columbia." By Mr. James Ashworth.

"An Improved Watering-tub for Laying Dust in Coal-mines." By Mr. Henry Lawrence.

"The Dust-danger." By Mr. W. H. Pickering.

"An Improved Apparatus for Laying Dust in Coal-mines." By Mr. J. Cresswell-Roscamp.

"The Effect of the Watering of Coal-mines on the Spread of Ankylostomiasis." By Mr. Jonathan Wroe.

The occurrence of fires and rescue-appliances have been described in the following papers:—

"The Problem of Gob-fires." By Mr. George Farmer.

"The Work of a Joint Colliery Rescue-station." By Mr. M. H. Habershon.

"An Outbreak of Fire, and its Cause, at Littleburn Colliery." By Mr. M. F. Holliday.

"The Occurrence of Underground Fires at the Greta Colliery, New South Wales." By Mr. Joshua Jeffries.

"Fire in a Lanarkshire Colliery, and Description of a Condenser used thereat." By Mr. James C. Weir.

The recent history of explosives is set forth in the following paper:—

"The Development of Explosives for Coal-mines." By Mr. Donald M. D. Stuart.

The utilization of the waste-heat of coke-ovens is described in the following papers:—

"The Firing of Babcock and other Boilers by Waste-heat from Coke-ovens." By Mr. T. Y. Greener.

"The Utilization of Surplus-gases from Bye-product Coke-ovens." By Messrs. G. Blake Walker and L. T. O'Shea.

The application of conveyors in mines is the subject of two papers:—

"The Mickley Conveyor." By Mr. J. W. Batey.

"The Conveyor-system for Filling at the Coal-face, as Practised in Great Britain and America." By Messrs. W. C. Blackett and R. G. Ware.

The miscellaneous papers comprize:—

"Underground Horses at an Indian Colliery." By Mr. Thomas Adamson.

"Barometer, Thermometer, etc., Readings for the Year 1904." By Mr. M. Walton Brown.

"Note on a Natural Paraffin found in the Ladysmith Pit, Whitehaven Collieries." By Mr. R. Dodds.

"Note on the Composition of Coal from the Faröe Islands." By Mr. R. Dodds.

"The Taxation of Collieries." By Mr. Arthur Hassam.

"Notes on Safety-lamp Oils." By Dr. G. P. Lishman.

"Hennebique Ferro-concrete Construction." By Mr. S. S. Platt.

"Note on the Calorific Effect of Coal from the Faröe Islands." By Mr. R. R. Thompson.

"Note on the Composition of Dover Coal." By Mr. R. R. Thompson.

The preceding list, comprizing 80 papers, demonstrates the varied nature of the subjects dealt with in the *Transactions* (vols. xxviii. and xxix.). During the past year, "Notes of Papers (236) on the Working of Mines, Metallurgy, etc., from the Transactions of Colonial and Foreign Societies and Colonial and Foreign Publications" have been continued, and should prove of value to the members.

The report of the Council on the Coal-mines Regulation Act (1887) Amendment Act, 1903, and its effect upon the qualifications of candidates for certificates of competency, has been printed in the *Transactions*.

The Rev. G. M. Capell represented the Institution at the meeting of the Corresponding Societies of the British Association for the Advancement of Science, held at Cambridge on August 18th and 23rd, 1904.

The Institution of Civil Engineers have appointed a special committee to consider the education and training of engineers, and Prof. Henry Louis has been nominated to serve on the committee on behalf of this Institution.

An International Congress of Mining, Metallurgy, Engineering and Applied Geology was held at Liége, from June 25th to July 2nd, 1905, in conjunction with the Universal Exposition held in that city. The Council nominated Mr. H. C. Peake, Past-President and Chairman of the Council, to act as their delegate; he attended the Congress, together with a number of the members; and he was elected an Honorary President of the Mining Section. The cordial reception of the Belgian engineers was warmly appreciated by the members of this Institution who attended the International Congress.

A number of the members of the Association des Ingénieurs sortis de l'École de Liége visited England in September, 1904. They attended the Annual General Meeting held at Birmingham, and took part in the proceedings and visits to works, etc. Visits were also made by them to the North of England and South Wales, the arrangements for their entertainment being made by the North of England Institute of Mining and Mechanical Engineers and the South Wales Institute of Engineers respectively.

The International Jury of Awards of the Louisiana Purchase Exposition, 1904, has awarded a Gold Medal to the Institution for the exhibit of the *Transactions* in Group 119, and a Silver Medal to the Secretary, Mr. M. Walton Brown.

The thanks of the members are due to the North of England Institute of Mining and Mechanical Engineers, who have allowed, as hitherto, the Institution to have the use of their offices and stock-rooms during the past year, free of charge.

Dr. THE TREASURERS IN ACCOUNT WITH
FOR THE YEAR

	£ s. d.	£ s. d.
July 31, 1904.		
To Investment with River Tyne Commission	1,000 0 0	
„ Balance at Bank, Current Account	228 10 8	
„ „ „ Deposit Account	413 17 11	
„ „ in Cashier's hands	52 1 7	
		1,694 10 2
July 31, 1905.		
To Subscriptions for the Year ending July 31st, 1902—		
Non-federated—		
Mining Institute of Scotland		0 10 0
To Subscriptions for the Year ending July 31st, 1904—		
Federated—		
Midland Counties Institution of Engineers	6 13 0	
Midland Institute of Mining, Civil and Mechanical Engineers	6 13 0	
Mining Institute of Scotland	0 19 0	
North of England Institute of Mining and Mechanical Engineers	57 19 0	
North Staffordshire Institute of Mining and Mechanical Engineers	5 14 0	
South Staffordshire and Warwickshire Institute of Mining Engineers	14 5 0	
		92 3 0
To Subscriptions for the Year ending July 31st, 1905—		
Federated—		
Manchester Geological and Mining Society	143 9 0	
Midland Counties Institution of Engineers	323 19 0	
Midland Institute of Mining, Civil and Mechanical Engineers	292 16 3	
Mining Institute of Scotland	454 2 0	
North of England Institute of Mining and Mechanical Engineers	1,176 2 0	
North Staffordshire Institute of Mining and Mechanical Engineers	158 13 0	
South Staffordshire and Warwickshire Institute of Mining Engineers	60 16 0	
		2,609 17 3
Non-federated—		
Manchester Geological and Mining Society	25 0 0	
Mining Institute of Scotland	9 0 0	
		34 0 0
Carried forward		£4,431 0 5

THE INSTITUTION OF MINING ENGINEERS. Cr.

ENDING JULY 31, 1905.

July 31, 1905.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
By Printing—												
Transactions, vol. xxiii., plates ...	9	17	6									
				9	17	6						
" " xxiv., plates ...	1	10	0									
				1	10	0						
" " xxv., printing ...	109	17	6									
" " " plates ...	19	0	6									
				128	18	0						
" " xxvi., printing ...	172	8	3									
" " " plates ...	16	11	3									
				188	19	6						
" " xxvii., printing ...	435	9	9									
" " " plates ...	194	19	9									
				630	9	6						
" " xxviii., printing ...	548	9	5									
" " " plates ...	154	7	10									
				702	17	3						
" " xxix., printing ...	134	2	8									
" " " plates ...	25	5	0									
				159	7	8						
							1,821	19	5			
Excerpts, vol. xxiii.				4	17	6						
" " xxv.				6	18	10						
" " xxvi.				8	3	6						
" " xxvii.				24	5	1						
" " xxviii.				53	3	8						
" " xxix.				14	5	7						
							111	14	2			
Proofs of Papers for General Meetings							12	12	6			
Circulars							30	6	8			
										1,976	12	9
" Addressing *Transactions*, etc.							64	13	7			
" Stamps—Circulars				12	13	6½						
" " Correspondence				28	5	3½						
" " *Transactions*				411	14	5						
							452	13	3			
" Stationery, etc.							32	5	2			
" Insurance of *Transactions*							3	0	0			
" Binding—Library				7	6	2						
" " Sundries				0	3	6						
" " *Transactions*				21	14	3						
							29	3	11			
Carried forward							£581	15	11	£1,976	12	9

Dr. THE TREASURERS IN ACCOUNT WITH

	£	s.	d.	£	s.	d.	£	s.	d.
Brought forward							4,431	0	5
To Local Publications and Authors' Copies—	1903-1904.			1904-1905.					
The Institution of Mining Engineers... ...	16	8	9	7	11	2			
Manchester Geological and Mining Society...	0	0	0	7	9	0			
Midland Counties Institution of Engineers ...	0	0	0	0	0	0			
Midland Institute of Mining, Civil and Mechanical Engineers	0	0	0	5	16	9			
Mining Institute of Scotland	0	0	0	7	15	3			
North of England Institute of Mining and Mechanical Engineers	0	0	0	32	1	6			
South Staffordshire and Warwickshire Institute of Mining Engineers	0	14	6	0	10	6			
	17	3	3	61	4	2			
							78	7	5
To Sales of Transactions, etc.—	1903-1904.			1904-1905.					
The Institution of Mining Engineers	0	0	0	151	7	7			
Midland Counties Institution of Engineers ...	1	0	0	21	13	0			
Midland Institute of Mining, Civil and Mechanical Engineers	5	0	0	5	13	0			
Mining Institute of Scotland	0	0	0	3	13	0			
North of England Institute of Mining and Mechanical Engineers	1	0	0	21	17	0			
North Staffordshire Institute of Mining and Mechanical Engineers	1	0	0	4	13	0			
South Staffordshire and Warwickshire Institute of Mining Engineers	11	0	0	7	2	3			
	19	0	0	215	18	10			
							234	18	10
To Advertizements				451	16	4			
To Address Labels				1	10	0			
To Interest on Deposit Account				13	3	11			
To Income from Investments				38	0	0			
							504	10	3
							£5,248	16	11

THE INSTITUTION OF MINING ENGINEERS.—*Continued.* **Cr.**

	£ s. d.	£ s. d.	£ s. d.
Brought forward		581 15 11	1,976 12 9
By Reporting General Meetings		34 1 0	
„ Expenses of General Meetings		56 14 8	
„ Incidental Expenses		29 10 11	
„ Salaries, Wages, Auditing, etc.		789 17 6	
„ Indexing *Transactions*		46 4 6	
„ Travelling Expenses		7 18 5	
			1,546 2 11
„ Translation of Papers		3 19 3	
„ Abstracts of Foreign Papers, vol. xxvi. ...	40 0 10		
„ „ „ „ xxvii.	94 5 8		
		134 6 6	
„ Barometer Readings, etc.		5 5 0	
„ Calendars		17 13 6	
„ Prizes for Papers in vols. xxiv. and xxv.		24 0 0	
			185 4 3
			3,707 19 11
„ Adjustment of Excerpts :—			
Mining Institute of Scotland		1 17 0	
			1 17 0
„ Investment with River Tyne Commission		1,000 0 0	
„ Balance at Bank, Current Account		426 17 5	
„ „ „ Deposit Account, including Interest		111 13 9	
„ „ in Cashier's hands		0 8 10	
			1,539 0 0
			£5,248 16 11

We have examined the above account of receipts and payments, with the books and vouchers relating thereto, and certify that in our opinion it is correct.

JOHN G. BENSON & SONS,
Chartered Accountants.

Newcastle-upon-Tyne,
August 12*th*, 1905.

THE INSTITUTION OF
BALANCE SHEET.—

Liabilities.

	£ s. d.	£ s. d.
July 31, 1905.		
Sundry Creditors—		
Advertizements paid in Advance	31 2 6	
Printing, etc.	990 0 0	
Postage of Transactions	210 0 0	
Abstracts of Foreign Papers in Volumes xxviii. and xxix.	140 0 0	
Barometer Readings	8 0 0	
Prizes for Papers in Volumes xxvi., xxvii., xxviii. and xxix.	80 0 0	
Indexing Volumes xxvii., xxviii. and xxix.	60 0 0	
		1,519 2 6
Balance of Assets over Liabilities, exclusive of the Value of the Stock of *Transactions*, etc.		411 11 8

We have examined the above Balance Sheet, with the books and vouchers relating thereto, and certify that in our opinion it exhibits a correct view of the affairs of the Institution.

JOHN G. BENSON & SONS,
Chartered Accountants.

Newcastle-upon-Tyne,
March 8th, 1906.

£1,930 14 2

MINING ENGINEERS.
JULY 31, 1905.

Assets.

July 31, 1905.	£ s. d.	£ s. d.
Balance at Bank, Current Account	426 17 5	
" " Deposit Account, including Interest	111 13 9	
" in Cashier's hands	0 8 10	
Investment with River Tyne Commission	1,000 0 0	
" " " Interest to date	11 2 9	
		1,550 2 9
Subscriptions for the Year ending July 31, 1904, Unpaid—		
Federated—		
South Staffordshire and Warwickshire Institute of Mining Engineers	2 17 0	
		2 17 0
Subscriptions for the Year ending July 31, 1905, Unpaid—		
Federated—		
Manchester Geological and Mining Society	23 15 0	
Midland Counties Institution of Engineers	14 5 0	
Midland Institute of Mining, Civil and Mechanical Engineers	13 1 9	
Mining Institute of Scotland	1 18 0	
North of England Institute of Mining and Mechanical Engineers	87 8 0	
North Staffordshire Institute of Mining and Mechanical Engineers	9 10 0	
South Staffordshire and Warwickshire Institute of Mining Engineers	37 1 0	
		186 18 9
Non-federated—		
Manchester Geological and Mining Society	3 0 0	
		3 0 0
Local Publications and Authors' Copies, Unpaid—		
Institution of Mining Engineers	17 16 6	
Mining Institute of Scotland	2 3 0	
North Staffordshire Institute of Mining and Mechanical Engineers	1 1 6	
South Staffordshire and Warwickshire Institute of Mining Engineers	4 6 3	
		25 7 3
Transactions Sold, Unpaid—		
Midland Counties Institution of Engineers	8 0 0	
North of England Institute of Mining and Mechanical Engineers	1 0 0	
South Staffordshire and Warwickshire Institute of Mining Engineers	3 0 0	
		12 0 0
Advertisements, Unpaid		150 8 5
		£1,930 14 2

THE LOCAL INSTITUTES IN ACCOUNT WITH THE INSTITUTION OF MINING ENGINEERS, FOR THE YEAR ENDING JULY 31ST, 1905.

Dr.	No. of Members. Federated.	No. of Members. Non-federated.	Balance due at the beginning of the year. £ s. d.	Amounts falling due during the year. Calls made during the year £ s. d.	Excerpts. £ s. d.	Transactions, £ s. d.	Totals. £ s. d.
Manchester Geological and Mining Society	176	56	0 0 0	195 4 0	7 9 0	0 0 0	202 13 0
Midland Counties Institution of Engineers	356	...	7 13 0	338 4 0	0 0 0	29 13 0	375 10 0
Midland Institute of Mining, Civil and Mechanical Engineers	322	...	11 13 0	305 18 0	5 16 9	5 13 0	329 0 9
... .	480	18	0 19 0	465 0 0	9 18 3	4 3 0	480 0 3
f Mining and Mechanical Engineers	1,330	...	58 19 0	1,263 10 0	32 1 6	22 17 0	1,877 7 6
e of Mining and Mechanical Engineers	177	...	6 14 0	168 3 0	1 1 6	4 13 0	180 11 6
South Staffordshire and Warwickshire Institute of Mining Engineers...	103	...	28 16 6	97 17 0	4 16 9	10 2 3	141 12 6
Totals	2,944	74	114 14 6	2,833 16 0	61 3 9	77 1 3	3,086 15 6

Cr.	Amounts paid during the year. Balance from previous years. £ s. d.	Calls. £ s. d.	Excerpts. £ s. d.	Transactions, etc. £ s. d.	Totals. £ s. d.	Balance due at July 31st, 1905. £ s. d.
.. ...	0 0 0	168 9 0	7 9 0	0 0 0	175 18 0	26 15 0
... ...	7 13 0	323 19 0	0 0 0	21 13 0	353 5 0	22 5 0
Engineers	11 13 0	292 16 3	5 16 9	5 18 0	315 19 0	13 1 9
... ...	0 19 0	469 2 0	7 15 3	4 3 0	475 19 3	4 1 0
Engineers	58 19 0	1,176 2 0	32 1 6	21 17 0	1,288 19 6	88 8 0
anical En-	6 14 0	158 13 0	0 0 0	4 13 0	170 0 0	10 11 6
of Mining Engineers	25 19 6	60 16 0	0 10 6	7 2 3	94 8 3	47 4 3
Totals	111 17 6	2,648 17 3	53 13 0	66 1 3	2,874 9 0	212 6 6

BOOKS, ETC., ADDED TO THE LIBRARY.

African Review, London. Vol. xl., Nos. 611-619; and vol. xli., Nos. 620-632.

Annales des Mines de Belgique, Bruxelles. Vol. ix., Nos. 3 and 4; and vol. x., Nos. 1-3.

Australasian Institute of Mining Engineers, Melbourne. Transactions, vol. x.

British Association for the Advancement of Science, London. Report of the Seventy-third Meeting, held at Southport in September, 1903; and Report of the Seventy-fourth Meeting, held at Cambridge in August, 1904.

British Society of Mining Students, Manchester. Journal, vol. xxvi., Nos. 4-6 and Index; and vol. xxvii., Nos. 1-4.

Chemical and Metallurgical Society of South Africa, Johannesburg. Journal, vol. iv., No. 12; and vol. v., Nos. 1-12.

Cory Brothers & Company, Limited, Cardiff. British Coal and Freight Circular and General Export List, July 31st, 1904, to April 30th, 1905.

Cuerpo de Ingenieros de Minas del Perú, Lima. Boletín, Nos. 8 and 10-23.

Engineering and Mining Journal, New York City. Vol. lxxviii., Nos. 4-26; vol. lxxix., Nos. 1-26; and vol. lxxx. Nos. 1-4.

Engineering Times, London. Vol. xii., Nos. 78-98; vol. xiii., Nos. 99-124; and vol. xiv., Nos. 125-130.

Franklin Institute of the State of Pennsylvania, Philadelphia. Journal, vol. clviii., Nos. 2-6; vol. clix., Nos. 1-6; and vol. clx., No. 1.

Geological Institution of the University of Upsala, Upsala. Bulletin, vol. vi., Nos. 11 and 12.

Institution of Mining and Metallurgy, London. Transactions, vols. xii. and xiii.

Manchester Geological and Mining Society, Manchester. Transactions, vol. xxviii., Nos. 16-20.

Massachusetts Institute of Technology, Society of Arts, Boston. Technology Quarterly, vol. xvii., Nos. 2-4; and vol. xviii., No. 1.

Mining Society of Nova Scotia, Halifax. Transactions, vol. viii.

New South Wales, Department of Mines, Sydney. Annual Report, 1904.

New Zealand, Department of Mines, Wellington. Annual Report, 1904.

Queensland, Department of Mines, Brisbane. Annual Report, 1904.

—, — — —, —. Year-book, 1905.

Queensland Government Mining Journal, Brisbane. Vol. v., Nos. 49-55; and vol. vi., Nos. 56-60.

South Wales Institute of Engineers, Cardiff. Transactions, vol. xxiv., Nos. 1-4.

United States, Geological Survey, Washington. Bulletin, Nos. 228-241.

—, —, —. Mineral Resources of the United States, 1903.

—, —, —. Professional Papers, Nos. 22-28.

—, —, —. Water-supply and Irrigation Papers, Nos. 95-118.

Western Australia, Department of Mines, Perth. Annual Report, 1903.

EXCHANGES.

Annales des Mines de Belgique.

Australasian Institute of Mining Engineers.

British Association for the Advancement of Science.

British Society of Mining Students.

*Canadian Mining Institute.
Chemical and Metallurgical Society of South Africa.
Cuerpo de Ingenieros de Minas del Perú.
Franklin Institute of the State of Pennsylvania.
Geological Institution of the University of Upsala.
*Institution of Mechanical Engineers.
Institution of Mining and Metallurgy.
*Lake Superior Mining Institute.
Massachusetts Institute of Technology.
Mining Society of Nova Scotia.
*Natal, Geological Survey of the Colony of.
New South Wales, Department of Mines and Agriculture, Geological Survey.
*North-east Coast Institution of Engineers and Shipbuilders.
*Revue Universelle des Mines, de la Métallurgie, etc.
South Wales Institute of Engineers.
*Transvaal, Department of the Mining Commissioner.
United States Geological Survey.

* No publications received during the current year.

July 31st, 1905.

The PRESIDENT (Sir Lees Knowles, Bart.), then took the chair.

DISCUSSION OF MR. F. HIRD'S PAPER ON "THE ELECTRICAL DRIVING OF WINDING-GEARS: SUPPLEMENTARY NOTE."*

Mr. W. C. MOUNTAIN (Newcastle-upon-Tyne) wrote that the following corrections should be made in his remarks† upon this paper:—Line 3, "when accelerated" should read "during acceleration"; line 16, "it was more economical" should read "it was generally more economical"; and line 20, "an engine winding at the rate of 120 feet per second" should read "an engine winding at the speed of about 70 feet per second."

Mr. JOSEPH DICKINSON read the following paper on "The Leading Features of the Lancashire Coal-field":—

* *Trans. Inst. M. E.*, 1903, vol. xxv., page 592; and vol. xxix., page 392.
† *Ibid.*, vol. xxix., page 396.

THE LEADING FEATURES OF THE LANCASHIRE COAL-FIELD.

By JOSEPH DICKINSON, F.G.S.

I.—Introduction.

The Lancashire coal-field has been described by numerous authors. Many of the monographs appear in the *Transactions* of the Manchester Geological (and now Mining) Society. The first two of these in 1839, followed by a third in 1840, were written by that able pioneer and practical geologist, Mr. Edward William Binney, who added many others afterwards. Following on in 1862, came the present writer's first paper, with a detached sheet of sections of the strata, some of which were by eminent mining engineers whose names are duly acknowledged in the text.* It would be a long list to specify all the writers. Suffice it to say that in 1904, came one by Mr. Herbert Bolton on the palæontology, and one on the Bradford (Manchester) part of the coal-field by Mr. John Gerrard.

In 1865, at the request of the Lancashire and Cheshire Coal Association, the present writer gave to the North of England Institute of Mining Engineers, on their visit to Manchester, a short paper on "Some of the Leading Features of the Lancashire Coal-field," which is printed in their Transactions.† Being now asked by the Council of the Manchester Geological and Mining Society to give a paper on the same subject to The Institution of Mining Engineers on the occasion of their 1905 visit to Manchester, and since it is superfluous to repeat details, what he now proposes is to outline very briefly the 1865 paper, and with additions to endeavour to bring it up to date.

II.—Outline.

The maximum thickness of the Carboniferous formation in Lancashire is about 4,850 yards. This consists of:—The Coal-

* *Transactions of the Manchester Geological Society*, 1862, vol. iv., page 155.

† *Trans. N. E. Inst.*, 1865, vol. xv., page 13.

measures, about 2,150 yards; the Millstone Grit, with accompanying strata, 2,000 yards; and the Mountain Limestone, 700 yards.

The coal-field in point of thickness, number of seams and variety of coal, is comparable with the thickest coal-fields of the kingdom.

The Millstone Grit, notably between Burnley and Chatburn, differs very much from the thin representative strata of farewell rocks, shales and conglomerate, as seen on the northern outcrop in South Wales, or as compared with the much thinner representative between Durham and Cumberland.

The Mountain Limestone, next below, is more divided into masses with intermediate strata and the usual minor divisional bedding, than the more solid mass in Wales, the division into masses being completed further north.

The outcrops of the coal-field are traceable round the outskirts, the crop of the lower coal-seams being mainly on high ground. These outcrops are not always in parallel lines, but often disconnected and altered by change of dip and faults. The chord-line, across where the coal-field is overlain by unconformable New Red Sandstone, Permian Marls and Permian Sandstone, is usually of low elevation.

Consequent upon the great thickness of the coal-field, it has been found convenient by mining engineers to divide it into three series—the Upper, Middle and Lower. The Upper Series counts from the top down to and including the Worsley and Pendleton Top Four-foot seam. The Middle Series, from the Worsley Four-foot down to and including the Arley seam. The Lower Series from the Arley down to the lowest seam: this Lower Series, from the fact that many of the outcrops are on the hills, is sometimes called the Mountain Mine Series. The coal in the Upper Series is usually swifter burning than that in the other series—the Worsley Four-foot having long been prized as suitable for bakers' ovens and shortage of boiler-power. Other seams are often known by names corresponding to the special purposes which they suit. Some geologists have demurred to the division of the coal-field into series; but, for ordinary practical purposes, the division is found too convenient to be given up.

In dealing with numerous sections of strata it should be understood that in some the thickness is measured at a right

angle to the bedding, whilst in others (as in vertical shafts through dipping strata) it is usually measured vertically, which shows more thickness. Consequently, in comparing sections, allowance is required for the difference. And further, actual discrepancies have sometimes to be rectified in sections of shafts and bore-holes which pass through faults, the throw of which causes some strata to be missed and lessens the distance to lower seams; whilst on rare occasions, in contorted strata, a vertical shaft might pass three times through the same seam.

III.—Variations in the Coal-field.

Tracing the coal-field from point to point, some strata are found continuing over long distances with few changes, and others changing variously. These variations arise from:—(*a*) Faults; (*b*) changes of dip; (*c*) intervening strata; and (*d*) variation of coal-seams.

The following are instances of change:—

(*a*) *Faults.*—Faults cause the greatest displacements. They are numerous, and the coal has to be worked in the belts between them.

The largest fault comes through Bolton and by the Irwell valley to Pendleton. At Darcy Lever Hall, the Worsley Top Four-foot coal, at the bottom of the Upper Series, crops out against the downthrow side of the fault, and at the opposite side are the strata near the bottom of the Middle Series, showing a throw of about 1,000 yards, and for 3 miles southwards the Four-foot coal and strata above it are absent. At Pendleton, where the crop of the Four-foot comes against the upthrow side of the fault, New Red Sandstone and Permian are in at the downthrow side; (from underneath which, about 2 miles northwards, the Four-foot emerges) the difference of distance at the reverse positions being occasioned by difference of dip. This great fault has been cut through, and, as seen by the writer, was found to be of great width, verifying the old observation "the wider the fault-vein the greater the throw."

(*b*) *Changes of Dip.*—Changes of dip come next in varying the courses. The dip east of Blackburn through Great Harwood is almost vertical, with the summit occasionally turned over in the reverse direction, and different elsewhere. Dips in the

interior vary from 1 in 2 to nearly horizontal. Common dips are 1 in 3 and 1 in 5.

The overlying unconformable formations usually dip in similar direction with the coal-bearing strata, but generally at a different rate.

(*c*) *Intervening Strata.*—New beds intervening sometimes occasion change, which, unless followed step by step, is difficult to trace. Sandstone-rocks are perhaps the most intrusive. With them, as is sometimes said, "the coarser the structure, the shorter the range."

(*d*) *Variations of Coal-seams.*—Variations of coal-seams are often very important. Dirt-bands come in between the beds of some coal-seams, and occasionally thicken into varied strata, and then further away the coal-beds either re-unite or become dispersed.

IV.—The Coal-measures.

Upper Series.—The Worsley and Pendleton Top Four-foot seam, at the base of this series, is an instance of long continuance with little change. It has been extensively worked south of the Irwell-valley fault from Bedford-Leigh, through Astley, Worsley, Patricroft and Pendlebury to Pendleton, in the course of which it is crossed by large faults. It has also been worked north of the Irwell-valley fault, from Darcy Lever Hall, ¼ mile north-west of the confluence of the Croal with the Irwell to 2¼ miles eastwards.

Instances of change in this Upper Series are given in part V. of this paper, on the Manchester portion of the coal-field, in which the correlation of this Four-foot seam has long been debatable.

Middle Series.—In the Middle Series are many changes, of which the following are some, in descending order:—

The Ince and Gidlow group of coal-seams at Wigan become the Binn, Shuttle, Crumbouke, Brassy and Rams eastwards. In this course, the seam now generally called the Rams, has been and is still occasionally known as the Seven-foot and the Six-foot. At Clifton, the Shuttle and Crumbouke lie 15 yards apart: at Great Lever, Little Lever and Radcliffe, they are united and form the Upper Three-yard. The Brassy seam,

between the Crumbouke and the Rams, entirely disappears between Clifton and Pendlebury colliery, being replaced by sandstone-rock; and, in the same range, the top coal of the Rams disappears.

The Pemberton Five-foot, Two-foot and Four-foot, respectively 12 and 15 yards apart at Wigan, maintain about the same lie as far as Haydock where they are named the Florida, but at St. Helens they become apparently the Higher and Lower Main delf, only 4 yards apart. East of Wigan, at Abram, Westleigh, Tyldesley and Shakerley, the Two-foot and Four-foot are united as the Great Seven-foot; farther east, separation sets in, so that at Worsley, Kersley, Clifton and Pendlebury they are the White and Black seams, 30 yards apart. Near Bolton, the beds are united as the Lower Three-yard or Ten-foot, which continues until the lower part separates into a distinct seam called the Gingham: the Ten-foot above holding on. Farther east, at Radcliffe Bridge, the beds become so separated as to have as yet been but little worked.

The wellknown Wigan Cannel coal (now represented mainly by exhausted workings) and the King coal-seam below, undergo many changes. Elsewhere, the Cannel disappears, and is often replaced by ordinary coal, with the King coal diverging, as at Westhoughton, to 17 yards or so, and becoming known as the Sapling. Farther away, at Stonecleugh, Clifton, Ainsworth, Radcliffe and Elton, with sometimes a trace of cannel on the top, the seam has been extensively worked. At Elton, it becomes known as the Hynes mine, with the Sapling coming close up near Bury. Then, beyond a large vacant area, at Middleton, the seams are usually considered to correlate with the Bent mines united, and at Oldham as the Upper and Lower Bent seams, and at Ashton-under-Lyne as the Two-foot and Peacock, about 20 yards apart.

The Wigan Plodder, Yard, Half-yard, Three-quarter, and the Arley group are the lowest seams of the Middle Series. The Yard and the Arley have been extensively worked, the others partially. Most of these seams thin eastwards, some disappear, and, north of the Irwell-valley fault, they are almost entirely unrecognized. At Elton and Bury, a coarse thick seam called the Dogshaw appears (after a few traces), and has been worked. The Dogshaw from its position has been assumed to be

the Arley; but, from other associations, it seems more likely to be the Plodder revived. Beyond Bury, the entire Middle Series disappears for some distance. A seam reappears in similar position at Rochdale, Heywood, and other detached places, and is called the Royley. The corresponding seam is also called the Royley, where the main coal-field crops out east of Oldham and Ashton-under-Lyne.

In the Burnley part of the coal-field, where the Middle Series reappears, the lowest seam in the series was formerly called a Four-foot, but latterly for distinction has been called the Arley.

A shell-bed, with remarkably large fossil shells, long called *Anthracosia* (but now seemingly referred to as *Anthracomya* or *Carbonicola robusta*), lies a few yards above the Arley mine at Wigan and in the vicinity.

Lower Series.—In the Lower Series, variations occur similar to those described in the Upper and Middle Series. Several of them are mentioned in the writer's former papers, and need not be repeated here. Suffice it to mention the change in position between the Upper Foot and the Gannister coal-seams. For a long range north-east of Oldham, these two seams lie about 15 yards apart. In the Upper Foot coal are spherical concretions, called "bullions," and in the roof over the coal are lenticular cakes containing numerous fossil shells (*Goniatites*, etc.) and some vegetable matter. When struck, these cakes emit an odour like garlic. The water from the coal, etc., yields much ochre, and, like nitric acid, it temporarily discolours a person's skin. Near Portsmouth (Cliviger), and Tooter Hill (Bacup), and notably Wholaw old colliery (3 miles south of Burnley), where the writer has seen the transition, the Upper Foot dips steeply down and unites with the Gannister coal. The two seams continue united as the Gannister Four-foot through the Burnley part of the coal-field to Colne, with the same characteristics continuing as those appertaining to the Foot coal before the union. The same kind of fossils also appear with the seam at Ingleton in Yorkshire, and are of great diagnostic value. At Wholaw, where the seams unite, the floor contains masses of iron-pyrites.

It is only the Lower Series which connects the Burnley part with the main coal-field. It is an improving series northwards, appearing ultimately, in greatly expanded form, as the great Durham and Northumberland coal-field.

V.—MANCHESTER PORTION OF THE COAL-FIELD.

The Manchester portion of the Lancashire coal-field requires special mention. It is surrounded by large faults and unconformable New Red Sandstone and Permian.

As it is thus isolated from the main coal-field, with the strata varied and different nomenclature of seams, diverse opinions have long been held on the correlation. The debates have centred chiefly on the question whether the Bradford (Manchester) Four-foot coal is identical with the Worsley and Pendleton Top Four-foot.

In 1879, Mr. Clegg Livesey, one of the old firm of owners of the Bradford colliery, in giving the section of strata of the Parker pit to the Manchester Geological Society, stated that formerly the firm supposed the Bradford Four-foot to lie about 300 yards above the Pendleton Crumbouke and Rams group of seams, but that after many explorations, one a shaft extending through the Bradford Four-foot at 110 yards to a thick rock and then by bore-hole to a total depth of 700 yards, they failed to find the Crumbouke and Rams series, the best seam met with being at 550 yards and that only about 3 feet in thickness, which they had named the Parker after the lord of the manor, and were working.*

Since the decease of Mr. Livesey, the present owners of Bradford colliery have extended the explorations to nearly 350 yards below the Parker mine, where they have found coal to which they are sinking, and expect to reach it by a shaft at a depth of about 900 yards below the surface. A cross-measure drift, dipping steeply across the strata, which dip at the rate of about 1 in 3, has already reached the coal, and the shaft has passed through the Parker.

The continuous section thus proved at Manchester consists of:—

	Yards.	Yards.
Ardwick Limestone, in twelve beds (24 feet 10 inches) with strata		157
Coal-measures cropping out to top of Bradford shafts		330
Bradford shafts to Bradford Four-foot	110	
Do. do. below Bradford Four-foot to Parker ...	440	
Do. drift, below Parker seam to coal	350	
		900
Total thickness proved		1387

* "Section of Strata at Bradford Colliery," by Mr. Clegg Livesey, *Transactions of the Manchester Geological Society*, 1879, vol. xv., page 161.

The principal beds of the Ardwick Limestone have been worked extensively. The mines are now closed, and the deep shaft is used as a pumping-station; it seems desirable, therefore, to repeat the section furnished several years ago by Mr. William Mellor, who managed the mines for many years.

SECTION OF THE ARDWICK LIMESTONE STRATA, MANCHESTER.

Commencing (under 4 feet 6 inches of marl) below the Permian Sandstone.

Description of Strata.	Thickness. Ft.	Thickness. In.	Depth. Ft.	Depth. In.
First Limestone ...	1	2	1	2
Dark clay-floor, 8 inches; red clay, 10 feet ...	10	8	11	10
Second Limestone, with open joints	1	4	13	2
Grey clay-floor, 6 inches; clay, 11 feet	11	6	24	8
Third Limestone ...	1	4	26	0
Hard red clay	13	6	39	6
Fourth Limestone ...	0	10	40	4
Very hard red clay ...	36	0	76	4
Fifth Limestone ...	1	0	77	4
Grey and red clays ...	24	0	101	4
Sixth Limestone ...	2	0	103	4
Clay, 23 feet; gritstone, 1 foot; gritty shale, 21 feet; clays, 54 feet	99	0	202	4
Seventh Limestone ...	4	0	206	4
Red and green shale-beds	15	0	221	4
Eighth Limestone .	3	0	224	4
Red and green clays ...	4	0	228	4
Ninth Limestone (occasional)	1	0	229	4
Clays and shales, with calcareous courses ...	15	0	244	4
Tenth Limestone ...	1	6	245	10
Shales and grits, 45 feet; coal and black-band ironstone, 1 foot 6 inches; and sandy shale, 6 feet	52	6	298	4
Eleventh Limestone, main seam in six beds, limestone, 5 feet 4 inches; shale, 3 feet 8 inches	9	0	307	4
Red, etc., shale, 60 feet; COAL, 6 inches; floor, 6 feet	66	6	373	10
Large calcareous nodules	0	10	374	8
Shale and Holt Town sandstone, 81 feet; red shale, 15 feet ...	96	0	470	8
Twelfth Limestone and red ironstone ...	2	0	472	8

Some of the limestone is of brecciated structure. The lime produced has the property of a slowly-setting cement, which for many years was highly valued as the best for bricking in colliery-shafts.

The colliery-workings in the Manchester portion have extended from near the river Irk (partly under the slope of St. George's fault, Rochdale road), to beyond Belle Vue, Hyde road, a distance of 3 miles on the level course. Several seams of coal have been worked, most of them thin:—The Openshaw seam, to a small extent, chiefly for fire-clay; the Charlotte, Three-quarter, Four-foot, Yard and Parker; also a little of the New, the Doctor, and Two-foot, which lie between the Yard and the Parker. A thin coal and fire-clay have also been mined to a small extent at Hendon Vale, Smedley, in the valley of the Irk.

Most of the workings were closed before the 1872 Coal-mines Regulation Act first made the deposit of record-plans obligatory.

This requirement, now continued by the 1887 continuing Act, makes such deposits private for 10 years, except with the owner's consent. But under the 1896 Act, view is allowed for purpose of safety, with consent of the Secretary of State. Consequently, plans of the earlier workings were not so deposited. But the plan of the Bradford Four-foot was so deposited, and 10 years having expired, it is free to be viewed at the Home Office, Whitehall, London. The plan throws much light on this part of the coal-field; and it is an instructive record of how the extensive dip-workings were won underneath the dead water of former workings, and how in parts of deep workings pillars (40 yards wide with 20 yards workings between) were considered best for surface-support.

Strangers viewing this plan of the Four-foot mine may wonder what stopped the extension of the workings northwards to St. George's fault. The reason is said to be one of the cautions against disposing of property in small holdings without reserving the minerals.

As to the correlation of the strata of the Manchester part of the coal-field with the strata at Pendleton, it may be thought an easy task, having about 1,387 yards for the comparison. The writer of this paper has long known the upper part of the section. Now he has been kindly made acquainted with the lower portion. Yet throughout the whole, the division of seams precludes hasty identification. The additional evidence appears to strengthen the view that the Bradford (Manchester) Four-foot coal-seam is identical with the Pendleton and Worsley Top Four-foot.

The difficulty of reconciling this view has all along been the absence, from the Bradford strata, of seams of coal corresponding with those that occur in the Rams group west of Manchester. Actual proof is still wanting. In endeavouring to explain this want, the writer is forced to the conclusion that, at Bradford, important portions of this group have become displaced by the thick sandstone-rock, 300 yards below the Four-foot coal. He describes, in Part IV. of this paper, the proved displacement at Pendlebury of the whole of the Brassy seam from this group by the intervention of sandstone-rock. Apparently, therefore, the displacement is increased at Bradford.

As to the lower seams at Bradford, the Parker, (a white-ash coal) probably accords with the White coal of the Pemberton

It is dislocated by large faults, altered by dips, change of strata, including coal-seams. Each fault, as usual, slopes towards the downthrow side at an obtuse angle from the bedding of the strata, no matter how the strata dip.

The largest fault has corresponding strata, 1,000 yards higher at one side than at the other side; but the surface of the ground is levelled off to the same altitude at both sides, similarly to other faults. Over this levelled-off surface, there is ordinarily, up to a certain elevation, a covering of drift composed of clay, sand and pebbles, dragged or conveyed from distant outcrops, the whole lying unconformably upon the strata beneath. These disappearances of strata from the upthrow side of faults, and the disappearances of very much larger masses of ground shown by vacancies, are accounted for geologically by imaginary denudation and ice-flows.

Vast areas of the best coal-seams at moderate depths have been worked: some entirely, leaving the vacant goaf compressed between the roof and floor of the mine; and some with pillars of coal, varying from one-fourth to two-thirds of the whole, left purposely for surface-support.

Workings have already attained a depth exceeding 1,160 yards below the surface.

Places for new winnings within the area of the coal-field proper are few and difficult to find; thus, forcing an increasing number of sinkings to pierce the overlying watery formations on the dip.

Possibly the first surprise of the intelligent mining engineer-visitor from comparatively faultless coal-fields may be to find that, among such large dislocations, coal is produced from between the belts as cheaply as in many other districts.

Mr. James Ashworth proposed a vote of thanks to Mr. Dickinson for his interesting paper.

The President (Sir Lees Knowles) seconded the vote of thanks, which was cordially adopted.

Mr. R. L. Gamlen read the following paper on "Electrical Power-distribution":—

ELECTRICAL POWER-DISTRIBUTION.

By ROBERT LORAINE GAMLEN.

Although electricity in a vague way has been known for many hundreds of years, it is only lately that it has been made use of commercially. Its history is remarkable, more particularly as its application has progressed almost geometrically, at first slowly, then more quickly, until now the advance is so rapid that it is practically impossible to keep pace with the developments of the science.

The early experiments of Volta, Michael Faraday, and others, though they paved the way for all that is to-day, are too academic for this sketch. Perhaps 1856 marks the time when electricity was used at all for lighting commercially. In that year, the Siemens armature was invented, and from that date onward the light was used for lighthouses—in those days the only field-magnet used was the permanent steel magnet. In 1867, another and most radical advance was made: Siemens and Wheatstone supplanted the permanent magnet by the electro-magnet, and this advance gave the commercial dynamo.

In 1875, some arc-lamps were erected in Liverpool. From that date, various small sets with one engine, one dynamo and one arc-light were put on the market; they were used for lighting large open spaces, and still in 1879, Sir William Preece reported that "the electric light is only economical when one machine is used to produce one light." In 1878, the first arc-lighting stations were opened in London, when the Jablochkoff Company lit the Thames Embankment and the Holborn Viaduct. This was by means of the old Jablochkoff candles, which have long since been forgotten.

In 1878, Edison first brought out a form of incandescent lamp, the filament being of platinum-wire. In 1879, Sir Joseph Wilson Swan exhibited the first carbon-filament lamp at Newcastle-upon-Tyne. The possibilities of electricity, even in those

days, were so obvious that all the gas-shares throughout the country fell; as usual, in such cases, the slump went to preposterous lengths—electrical concerns also got an exaggerated support. The Anglo-American Brush Company took most advantage of this boom.

From 1880 onwards, the electric light-supply business has been in existence. In 1881, the Metropolitan Brush Company started a bulk-supply in London, and in 1882, the Jablochkoff Company erected another supply-station at Belvedere Road, for supplying both incandescent and arc-lighting in the Strand district.

Among the pioneers were the Colchester, Hastings and Eastbourne concerns, and several small concerns in London. These undertakings were worked in different ways:—(1) High-pressure direct-current machines: the Brush arc-lighter working with lamps placed in series across the terminals, both arc and incandescent. (2) High-pressure single-phase alternating, when the current was generated at the high pressure of 2,000 volts and distributed to transformers, there being converted to a working pressure of 50 to 100 volts. (3) Also in very condensed areas, direct-current systems were in use. Owing to the price of copper, high tension soon became a general practice, the facility of transformation, and the fact that the alternator had no commutator (always a source of trouble in the old direct-current machines), brought the single-phase alternating-current system into universal use, and for some considerable time this system was almost always adopted. This system developed, and in 1885, the London Electric Supply Corporation made a remarkable advance by putting down a station at 10,000 volts, thus early showing the way for the power-companies. Then, however, they had single-phase current only, and although they had the facility of transmission, they had not the means of turning the electrical power back into mechanical work. The single-phase motor was only a toy in those days; but that was not the only obstacle to the expansion of the industry. In 1882, the first Electric Lighting Act was passed, giving the Board of Trade powers to grant provisional orders to local authorities and companies for supply in certain areas. The local authorities possessed powers in perpetuity: the companies on the other hand had only 21 years, at the end of which time the local

authority could purchase the undertaking at the structural or scrap-iron value; and this, to a great extent, put a stop to electrical enterprise.

In the first year, 69 Orders were applied for, and as the applicants could not get any capital, in 1884 only four Provisional Orders were applied for, and in 1885 only one. It was not until 1888, when the Act was amended, extending the term of tenure to 42 years, that electric lighting by private enterprise became commercially possible.

The problem in the early days was practically that of lighting only, and, so far as that was concerned, the alternating single-phase system met the case admirably; but the plant had to be kept running all the 24 hours, although the hours during which light was used were from ½ hour to 3 hours in the summer, to 6 or 7 hours in the winter: consequently, the cost of running such undertakings was enormous. The interest-charges per unit sold were high, and the actual production-costs during the long idle hours swamped the concern. The enormous copper-expenditure that would have been necessary in low-tension mains, however, kept the system in force. The doubling of the pressure by the three-wire system altered conditions to a great extent: as then, with the use of a battery, the hours during which the machines had to turn were enormously reduced. The manufacture of the high-voltage lamp completed the change, and then all the new stations were built on the direct system, with generally three-wire distribution, and usually a declared pressure of from 200 to 250 volts. This change took place in about 1896. Although a great improvement had been made by the change, still the costs were high (not so much the actual working costs as the capital charges) owing to the short hours during which useful work was being done. The change to direct-current working gave the undertakings a chance to better their positions by taking on power-consumers during the day; many of the energetic concerns tried to make the best use possible of the chance, and to a large extent they met with great success, but they soon found many drawbacks. Owing to the large capital-expenditure in copper, necessary to transmit high powers, and to the fact that there was always a period of severe load when the lighting and power overlapped; and also, owing to the many

disadvantages inherent in a concern put down in the middle of a town and laid out to cater first for lighting, the price could not be brought down low enough to compete with the prices at which many industries could generate for themselves. These difficulties were soon recognized, and in 1900 the first of the power-company bills went before Parliament, aiming, by their great size and the variety of the industries which they could serve, at an economical method of dealing with the demand for cheap electricity.

Until quite recently in London, electricity was sold universally at 8d. per unit, but now the new Administrative County of London Company (whose bill, after steering through the extreme difficulties of the Committees of the House, and in the teeth of violent opposition, failed only to become law because of a day or two's time) has limited itself to a maximum price of 1½d., and prices as low as ½d. per unit in some special cases have been reached. As lately as two years ago, no coal-mines in this country took electricity from outside sources; but now power-companies have over 12,000 horsepower connected to their mains for collieries alone. These facts show clearly, then, that a vast change has taken place. It has been an evolution and an expansion, and a remarkably rapid one.

A typical case of a concern which has grown up and tried to cope with the changing conditions is the following:—

A lighting scheme was decided upon in 1896, and, as lighting was the only object at that time, naturally alternate current was used. As the area was an extensive one, this served the purpose well; but, owing to the large capital and working expenses, there was a steady and regular loss. After a few years, the township wished to instal an electric-tramway system, and in consequence a direct-current system was then adopted. Still, owing to peak-load vagaries, a very large margin had to be allowed, and in order to help matters on vigorous steps were taken to obtain other motor-load. This effort met with success, but now the problem of transmitting the large power at present needed comes up, and shortly it will be needful to add a three-phase distribution to the existing plant. This case is representative of nearly all those concerns that have been at work for more than six or seven years, and one that has come out of its troubles so far

remarkably well; yet it is at best a compromise and a patchwork affair, and far enough from the ideal.

Fig. 1.—Power-Station at Radcliffe.

The large power-companies aim at nothing less than the highest; they are working steadily, with the object of supplying

all the power needed for all purposes. It is with this object before them that the designers and organizers have set out. In order to succeed in such an enterprize, it is clear that several things are necessary:—(1) The current must be as cheap as, or cheaper than, any other form of power; (2) the supply must be absolutely regular in pressure, etc.; and (3) the supply must be so constant that, but for a veritable "act of God," there cannot be a stoppage.

In order that the supply may be given cheaply, it is clear that the cost must be kept down at a minimum, and this is dependent on three things:—(*a*) Capital outlay; (*b*) working cost; and (*c*) the amount of work done.

(*a*) The small-supply concern, being generally bound to its own area, has little choice of site, and frequently it has to spend large sums on obtaining land, especially as the centre of a supply-district is generally taken, so as to minimize the copper spent on the mains; whereas the power-company can pick from a large area, and should be able to buy far more cheaply.

The town-supply, founded only for meeting the growing wants of its own little area, can put in but small plants. In so doing, it is at a great disadvantage compared with the power-company: for, not only is the price per kilowatt far more with the small plant, but the floor-space, and consequently the building area, is far in excess per kilowatt of that which is necessary for the power-company.

In the mains, also, there is a notable advantage to be credited to the power-company. The power-carrying capacity of a main of given copper-capacity varies as the pressure, but the drop in pressure varies in volts as the current. It must be borne in mind that the amount of electrical power is the product of the volts and amperes. The ordinary town-supply is 500 volts and that of the power-company 10,000 volts. Now, not considering the question of the supply being three-phase, but only the two voltages, a given cross-section of copper can carry a given quantity of current, and 20 times as much power will be transmitted along the same copper at 10,000 volts as at 500 volts: but the advantage does not end here. The important factor in voltage-drop is the percentage-loss, and not the actual number of volts. Now, with a certain current flowing in a

main, the drop in volts increases as the distance, so that, if in a certain distance, the voltage-drop were 50, in the case of the 500 volts supply, the loss would be 10 per cent., while in the case of the 10,000 volts supply the loss would be 0·5 per cent.; or, in other words, the current could be sent 20 times the distance for the same percentage-loss, that is, 20 times the power could be transmitted 20 times the distance with the same copper-section, if the pressure were 10,000 instead of 500 volts. In order to utilize the high voltage, however, a more expensive switchgear has to be used, and the current has to be transformed down at the working end: therefore it would not pay to adopt the high voltage in a small area, as the money spent on switchgears and transformers would outweigh the saving in copper. A radius of 2 miles is about the economic limit for the ordinary supply at 500 volts; rather more can be managed for traction, as the voltage-variation is not so important.

Taking these points, and many other small ones, which it would be tedious to enumerate, the capital cost per kilowatt installed by a large power-company should be from 50 to 25 per cent. of the least at which an ordinary town-supply concern could arrive.

The capital cost has now been shown as being, in the nature of things, less than in the case of a small undertaking. The same arguments are true to a great extent with individual works: the only extras for the supply are the dynamo, switchgear and mains; in the individual works, the floor-space, the buildings and the chimney, cost more per horsepower installed, and the cost of the individual small sets is larger per horsepower than the equivalent in the power-house. Still, although, in many cases, the advantage can be shown well in favour of the power-company, it must be confessed that, in many others, the reverse may be true. Then, so far as low cost of energy is concerned, the other two factors must be relied on.

(*b*) The working cost comprizes chiefly coal, wages and management. Coal is naturally a very important item. The internal combustion-engine has been often quoted as the solution of the problem; if it does diminish the coal-bill, that is its only excuse for existence, for the economy of the up-to-date large turbine-set is so high, that under ordinary conditions even

this diminution is not great. A really considerable saving can only be obtained by using the ammonia-recovery process, and selling the sulphate as a set-off to the coal-bill; but such a plant is not a very desirable adjunct to a 10,000 volts supply-station.

The arguments against the utilization of the gas-engine are chiefly constructional ones, the floor-space required for a 2,000 horsepower two-cycle gas-engine, without any auxiliary apparatus, being about 2,800 square feet; a Curtis turbine of the same capacity need only have 120 square feet, say, an area of 50 feet square as against 11 feet square; but 2,000 horsepower for a power-company is a smallish set, 8,000 horsepower being more like the useful standard size. No gas-engine of such a size has yet been constructed, and, if it were, it would be a horrible enormity. The time may come when the long-dreamed-of gas-turbine will become an accomplished fact; this will, of course, greatly change matters, and then steam may find a serious rival in the internal-combustion engine. Another objection to the gas-engine is that its angular velocity is not sufficiently constant, and, upon perfectly-even turning, a great deal of the utility of the modern power-company (especially in Lancashire) depends. The turbine, on the other hand, has an absolutely constant angular velocity. Further, experience has not yet demonstrated the reliability of a gas-engine exceeding 500 or 600 horsepower, and above all other things, it is essential that a power-company shall be reliable. The gas-plant has many peculiarities which are against its use: the repair-bill of the engine and of the producer is large, the huge size of a set entails a large staff to look after it, and the oil-bill in most cases is a very serious item. These and other considerations have made the designers of the power-companies fight shy of this method of reducing the coal-bill.

In the matter of coal, however, the power-company is in a better case than municipalities or private concerns. They can place their works at the pit-mouth, and avoid freight; they use larger units than could be required by other concerns, with a consequent higher efficiency; they can settle close to a good water-supply, which means a good vacuum, and also makes for economy; and their long hours of work minimize the stand-by losses. Owing also to the enormous amount of coal burned, the price is naturally "rock-bottom"; and the various conditions

reduce this item of expenditure to such an extent that the coal-cost per horsepower-hour is lower than can be attained, either by the town-supply or by the individual works.

The wages-bill is far less also: in the case where turbines are used, one driver and one greaser per shift can attend to four

Fig. 2.—Boiler-house at Radcliffe.

machines, or 8,000 to 10,000 horsepower; whereas if this power were split up into 20 different concerns, at the very least twenty drivers and several cleaners would be needed; so also with the stokers, two men can look after the mechanical stokers needful

to generate steam for this power, while at least 10 times this number would be needed in the other case. So also with the management: with huge concerns many times larger than the 10,000 horsepower plant abovementioned, the expenses under this head increase but little, whereas each little concern has to bear its own cost of management, and so the ratio becomes increasingly favourable to the power-company in actual production-costs.

(*c*) The third of the economic features of a power-company, and perhaps the most important, is the amount of work done, that is, the amount of units sold in relation to the greatest amount that could be sold if the whole plant were working at full load during the 8,760 hours of the year: this ratio is the load-factor of a concern. In electrical undertakings, the load-factor is calculated with the maximum demand on the station, instead of the total installed in the station. Taking this as a basis, the load-factor of a good town-supply ranges from 18 to 25 per cent., while the power-company would range from 45 to 60 per cent. In single industries, a mill ranges between 26 and 30 per cent., individual small ironworks range between 12 and 15 per cent., while tramways get as high as 23 per cent. It is difficult to say what the load-factor of a coal-mine would be, the circumstances of each mine being so different, depending on how much is done in each class of work (pumping, ventilating, hauling and winding): it might vary from 15 to 40 per cent.

The power-company should head the list, and one or two examples will make the matter clear. The ordinary town-supply in winter has a short period of heavy load from about 4·0 p.m. until 7·30 or 8·0 p.m. The coal-mine shuts down a good deal of the work at 4·0 p.m., so that when the demand for power ceases at the colliery, the lighting-load takes its place. Again, the load-factor of any one coal-mine may be 20 per cent., but the times of maximum would vary, with the result that the combined load-factor of three or four mines might be 30 per cent.

A great deal, however, can be done by the power-company to improve its load-factor. By the offer of a rebate, many consumers are glad to make small alterations in their working hours; a colliery can often manage to alter the hours of pumping so as to suit the power-company, for which the company can well afford to make a reduction.

One case in actual working is of great interest. There is a large county-borough with a big central supply power-station, which works both lighting and tramways. This concern anticipated an extremely heavy tramway-load during Whit-week, and

FIG. 3.—TURBINE-HOUSE AT RADCLIFFE.

to meet this it had to instal a great deal of extra plant. Now, had this work been done by a power-company, the works which the power-company drive would be standing idle during the holidays, and in consequence the natural diversity would have

helped to load up the plant that would otherwise have been slack owing to the holidays, and also would not have necessitated the spare plant which the county-borough had to instal. So, by natural differences in times of working in some cases, and assisted differences in others, the power-company can arrive at long working hours. And it is only the power-company that can get these results.

The areas of these great undertakings cover many hundreds of square miles. The Yorkshire Company has 1,800 and the Lancashire has 1,200 square miles. These large areas in industrial districts imply a great variety of power-users, with a considerable natural diversity of load. There are in the Lancashire district, for instance, collieries, quarries, cotton-mills, and all the allied trades, many of which can do work at night. There are also ironworks of all descriptions, and, besides these, the ordinary lighting and tramway-load is found in many townships. No such diversity can be hoped for by any mere town-supply. That this is of enormous importance, is shown by the fact that, in the case of one power-company, the horsepower of the motors installed amounted to four times that of the plant installed in the power-house. Thus, the power installed is only one quarter of the power required in the consumers' works, and the earning power of each horsepower of the power-company is far in excess of that of the individual user of machinery. It is, then, owing to this greater earning power, backed by the small labour and coal-charges, and helped by the small capital-cost, that the power-company can sell current at rates suitable to all.

Another important point is that the machinery, which the power-company drives for the consumer, should be turned at an absolutely constant speed. This is not so important in mines, perhaps, as in many other industries; still, it is an advantage in a colliery too. The curves showing the variation of the turning speed or the angular velocity of various classes of work are very interesting. Many works-managers will declare that the turning is perfect, yet when the recorder is put on very strange vagaries are seen, the regular changes at each period of the engine's stroke being often quite clearly shown. The power-company, with its great bank of turbines, alters all this. The turbine, having a constant inlet of steam, has a perfectly constant speed at all parts of the revolution, and being direct coupled to the

dynamo, makes the latter rotate also with absolute constancy (the generator gives a three-phase current). Now, the speed of the three-phase motor depends on the periodicity, and, as this depends on the speed of the generator, which is constant, the motor speed also does not vary. This is so important that, in some industries, the output has been increased by 10 to 20 per cent., on account of the change from the old driving methods. The small station, unfortunately, cannot reach this perfection, as the direct-current motor slows up with added load; and, as before explained, the small supply has to use direct current.

There must be no stop. Electricity taken from the modern power-company meets this condition better than any other known form of driving. It is only with concerns of really large size that it can be economical to utilize the best methods for assuring continuous supply; how this perfect safety is arrived at is dealt with later and more fully in the description of the station and of the methods of distribution. Briefly, each item of the plant is of the utmost perfection and simplicity: each section is independent, so that in case of a fault happening to one section, there is another ready to take its place; there are spares throughout; and the distributing switchboards are reduced down to the utmost simplicity. These have been in the past a fruitful source of breakdown, which is now happily removed. The mains also are in duplicate throughout, so that if a breakdown occurs on one route the other branch can be used. Scarcely any individual works possess any such stand-by plant, and, even in the best regulated works, a breakdown may occur. The power-companies do not expect to be immune from them, but all plant is so doubled that whatever happens there is the spare to take up the work.

These three necessary conditions, then, have been met by the power-companies; and, having accomplished that, they feel that success is assured.

The Lancashire Electric Power Company's station, at Radcliffe, is fairly typical, and a description of it may show how the advantages, which power-companies possess, have been made the most of.

The transmission at high pressures to long distances being so easy, the exact position of the station with respect to the load is not of such importance, consequently the best site

economically can be obtained. The site (Fig. 1) at Outwood, near Radcliffe, has very great natural advantages. It is on the banks of the Irwell, consequently there is plenty of condensing water; it is beside the Lancashire and Yorkshire railway, whereby railway-facilities are secured; and it is close beside a colliery, so that coal at pit-mouth prices can be obtained. There is a siding from the railway, taken right on to the company's land, running at the back of the boiler-house.

At a position opposite the boiler-house, the siding passes over a hopper into which the coal is tipped. From a level, a few feet below the bottom of this hopper, there is a slightly inclined track running into the boiler-house at a height of some 25 feet above the firing-floor. Along this track runs a trolley, which is filled from the containing hopper, weighed, and conveyed by gravity to the boiler-house; and on its way it picks up a counterweight which, when the trolley is automatically unloaded, returns the truck to the hopper. The truck is emptied into bunkers arranged along the lines of boilers, and above them. The coal passes down through the bunkers into electrically-driven chain-grate stokers below the boilers. Thus the coal is not touched by hand from the pit-mouth to the fire. The six boilers, being a first instalment (three on each side), are of the Babcock-and-Wilcox water-tube type, each capable of evaporating 20,000 pounds of water per hour, from 60° Fahr. to steam at a pressure of 160 pounds per square inch, and 150° Fahr. of superheat. The main flues are beneath the boilers, and pass out to two brick-lined steel-chimneys behind the boiler-house. The two banks of boilers face one another, and the alleyway is at right angles to the engine-room length (Fig. 2). This arrangement admits of a minimum length of steam-main, and is so planned that extensions can be made with the utmost facility. A ring steam-main is fed by all the boilers, and is complete in the boiler-house. From this ring each engine is supplied. The auxiliary plant calls for no particular remark.

The engines are of the turbine-type, and of 2,000 kilowatts capacity each (Fig. 3). One bank of boilers feeds two turbines, and these form one unit of plant. In this case the turbines are of the vertical type, and have some advantages, the floor-space being very small and the construction very simple. It is not until a concern arrives at a considerable size that the turbine can be

used effectively: it is generally considered that small machines are not so satisfactory, and certainly the larger the plant the greater is the advantage. The turbines drive direct on to

Fig. 4.—Switchboard Gallery at Radcliffe.

the three-phase 10,000 volts alternators, which are placed above them. The only point of power-company economics that affects the actual generating plant, besides the steady drive referred

to before, is the fact that the cost per kilowatt is less for the large sizes employed by the power-company than for those used by the smaller concerns.

The three-phase current generated at the high pressure of 10,000 volts is carried to the switchboard (Fig. 4). A great deal depends upon the design of this section: the operation must be easy, there must be no danger from fire, and the whole must be safe. The system known as "remote control" has been employed almost universally. Remote control means that none of the main current is taken to the operating board: the main current being taken to large oil-switches, each of the three limbs being placed in a separate stone cell. The switch-contacts are operated by means of a small motor and strong springs, and only the small motor is started from the operating board. None of the instruments are on the main cables, all being operated by means of transformers, which give a suitable ratio for the reading of the instruments. The danger of switchboard-trouble is overcome; no mains of large power are on the operating board, so that there is nothing to catch fire; and, even if any little accident did happen, it would not damage the main cables, as they are not near, and the supply would not, therefore, suffer. The whole working of this board is so simple and automatic that, while being safety itself, it can be easily looked after by one man. From the switching apparatus, the current passes out on to the mains, still at a pressure of 10,000 volts.

The general design of the station is perhaps a most important one from the power-company point of view. Each section of the station is built up in units, one bank of boilers feeds one section of turbines, each with their own auxiliary plant; and each bank of turbines feeds one section of the switchboard. These are so arranged that, in the case of a failure in any one part, the spare section can be put in immediately, and the faulty one disconnected. This is true also of the main cables, as beforementioned. Facility of distribution at high pressure has already been mentioned, and it is made the most of.

The mains run straight from the station; in one case, they run right up to the north and along the Rossendale valley, where they tap quarries, slipper-works, and the cotton-industry. To the west, they run out past the south of Bolton into the Westhoughton and Wigan districts, and generally are antici-

pated to serve the coal-district. Another main branch is run through Swinton, and it will serve the cotton-industry.

The loss in transmission is so small, that even at these great distances the combined main loss should not be more than 5 per cent. In many small town-concerns, this item reaches 10 and sometimes 15 per cent. The company serves either a township or the individual consumer; and, in the case of the Lancashire Power Company, this service is made on behalf of the township in which the consumer is located. In the case of serving a township, a small cheap sub-station is erected, and the ordinary distributing mains to supply small private users, both lighting and little motors, are laid down. By this means, the chief part of the working expenses and a great deal of the capital expense is saved for the township; and it is able to distribute to the consumers at a price which it could not hope to touch, if it had all the heavy burdens of capital-expenditure and wages to bear. In the case of the private consumer, the high-tension current is brought direct on to his premises, where a small sub-station of a few feet square is built, the current transformed down to a working pressure, and this is distributed through the works. The three-phase current being admirably suited for motor-work, only static transformers are needed, and consequently no superintendence is required for looking after the plant. The result is that current, generated under the most economical conditions possible at a central generating-station, whose capital-expenditure per effective horsepower is low, with very small transmission-loss, can be provided to the industries of the country, at as low a cost (nay, lower) than they could make it for themselves, giving them, at the same time, a power, which can always deal with very severe temporary overloads, which can ensure a perfectly even turning (and so prove of enormous value to any delicate operations), and which, at the same time, can secure immunity from any stoppage by means of the great simplicity of the system, combined with complete spares.

With these facilities, power-companies hope to become the practically universal providers of power for all purposes in the country. The reasons for the hope have been set forth; the future only can show whether these hopes will be fully realized.

Mr. SYDNEY F. WALKER (Bath) said that Mr. Gamlen claimed that electric-power companies could supply current at a cheaper rate than an industry could supply itself, but he ventured to controvert this opinion. Electric power-supply companies had, of course, great advantages in the large units that they were able to lay down, in the load-factor, and in the other points mentioned, such as erecting the station alongside a colliery, with water at hand, and so on; but in the case of iron-works or collieries, he (Mr. Walker) did not think it possible for any electric-power company to supply current at a lower cost than they could produce it themselves. The load-factor of coal-mines had not yet been thoroughly examined, but it depended on whether there was a heavy pump-load, and whether electricity could be used for winding. There was clear evidence that the cost of electrical winding was practically prohibitive in this country at the present time; and he understood that the winding-engine took practically 50 per cent. of the entire load of a colliery; the ventilating fan, 16 per cent.; and unless there was a big pump-load, there was not much left upon which to economize. There could be no saving by applying electric current to drive a ventilating fan, as a triple or quadruple expansion engine was an ideal motor for driving it: the fan was required to continuously produce a certain volume of air with a certain water-gauge, and, therefore, it could be driven by any engine that would generate power economically. The same argument would apply against the use of electricity to drive a big pump with a continuous load.

The Rev. G. M. CAPELL said that, in the adaptation of three-phase motors to fans, he had found great difficulty in reducing the speed, and at week-ends and holidays, it was necessary, in order to ventilate the mine, to keep the fan running at the single constant speed. He suggested the use of two fans, each driven by a tri-phase motor, the two fans working together at the same speed, so as to give the full quantity of air; but so arranged that one fan could be stopped and the other kept in operation. By this arrangement, either fan, working singly, would produce about 80 per cent. of the volume at about 60 per cent. of water-gauge of the two fans working together, the speed being constant throughout. This arrangement would have an import-

ant bearing on the question of economy; for, when the full volume of air was not required, the ventilation could still be maintained by one fan driven by a motor using half the power that would be expended on the two fans used conjointly under ordinary conditions or where one large fan was used.

Mr. C. C. LEACH said that cheap coal did not altogether depend upon the power-station being placed close to a colliery, because pit-prices depended on competition, and if the cost of carriage by road or rail from an adjacent colliery was 1s. a ton, the cost of the supply to the power-station would not unreasonably be increased by 10d. or 11d. per ton.

The PRESIDENT (Sir Lees Knowles, Bart.) proposed a vote of thanks to Mr. Gamlen for his interesting paper.

Mr. W. SAINT seconded the resolution, which was cordially adopted.

DISCUSSION OF MR. A. R. SAWYER'S PAPER ON "THE SOUTH RAND GOLD-FIELD, TRANSVAAL."*

Mr. A. R. SAWYER (Johannesburg, South Africa) wrote that the references to Figs. 2 and 3, Plate XXV., and Fig. 4, Plate XXVI.,† should be modified as follows:—

Lower Karroo: Ecca Beds, with a Coal-seam.
Dolerite.
Dwyka Conglomerate or Breccia, below Ecca Beds.

Mr. B. H. THWAITE's paper, "Can Explosions in Coal-mines, with their associated Toxic Fatalities, be prevented," was read as follows:—

* *Trans. Inst. M. E.*, 1904, vol. xxvii., page 546.
† *Ibid.*, page 554.

CAN EXPLOSIONS IN COAL-MINES, WITH THEIR ASSOCIATED TOXIC FATALITIES, BE PREVENTED?

By B. H. THWAITE.

Public Opinion and Colliery-explosions.—The disastrous explosion at the Cambrian collieries in the Clydach Vale, South Wales, produced a painful sensation throughout the country, accompanied by an impression in the public mind, represented by the protest made in the House of Commons by a wellknown member, inferring that sufficient precautions, scientific or otherwise, were not taken to prevent these explosions, or, at least, to secure miners from being killed by them.

A Century of Attempts to secure Immunity from Explosions.—Almost a century has elapsed since Dr. W. R. Clanny and Sir Humphrey Davy introduced lamps bearing their names, to secure the safety of coal-workers; and research and invention have ever since been continuously devoted to discovering means for preventing colliery-explosions, yet still explosions occur. This fact prompts the question that constitutes the headline to this paper. One is almost justified in promptly replying to the question by a direct negative. The law of chance will intervene, and however perfect the precautions may be in theory, the absolute prevention of explosions in the workings, of the marsh gas exuding from carbonaceous strata, will never be possible.

The Proportion of Deaths from Toxic Effects will be Reduced.—But, in the depressing gloom surrounding this fact, there is a bright gleam of light. It will be possible in the future to prevent the death of probably, say, 8 out of 10 men who die through the toxic influence of carbon monoxide, produced by the partial oxidation of coal-dust ignited by the explosive combustion of the marsh gas.

Thanks to the masterly investigations of Dr. John S. Haldane and his collaborators, and to their diagnosis of the influences that have proved fatal or injurious to the victims of coal-mine explosions, we know the cause of the fatal sting of these accidents; and it is now possible to devise practical methods by which the deadliness of colliery-explosions may be reduced down to a mere fraction of their present magnitude.

The Genesis of Coal-mine Explosions and their Toxic Associations.—The raising of the veil of mystery, exposing the simple truth of the cause of from 75 to 92 per cent. of the deaths associated with colliery-explosions, has prompted new investigations and exposed remarkable features in the hygienic environment of coal-mine workers. To understand this, it is advisable to analyse the genesis of coal-mine explosions and their toxic association:—

1. Carbonaceous and indeed nearly all geological strata, other than those of an igneous character, are porous.

2. These pores in solid carbonaceous strata are filled with a combustible gas, known in colliery technology as marsh gas.

3. These strata are, by the course of coal-mine operations, pierced with workings, and the marsh gas is thus provided with an outlet of escape.

4. When the atmospheric pressure in these workings falls rapidly to a low level, then the resistance to the exudation of the marsh gas from the carbonaceous strata is reduced, and the gas flows into the workings more freely, and in greater volume.*

5. The marsh gas diffuses into the air of the workings, and when it has attained a volumetric proportion of 5 per cent. of marsh gas to 95 per cent. of air, the mixture becomes in a minor degree explosive: the maximum degree requiring 9·47 per cent. of marsh gas to 90·53 per cent. of air.

6. The presence of a bright-red incandescent igniting agent will fire the explosive mixture of marsh gas and air.

7. Assuming that such an ignition-agent exists, either as a spark or as a flame, the explosion in a Clanny lamp, the breaking

* Applied science may yet contrive a well-guarded barograph, so arranged that it will automatically and audibly signal in the working-zone of a coal-mine, when the atmospheric pressure falls rapidly to a danger-level. Such an apparatus, strongly built, might be equipped so as to give audible signals when the barometric pressure suddenly falls to a dangerous extent.

of an electric incandescent lamp-globe, except when it is guarded with an independent (air or water) annular chamber,* the spark from the commutator of an electric motor or that from a pick-stroke, the flash from an exploded cartridge, the fusing of an electric conductor, or the breaking of a Davy lamp, will bring about an explosion and consequent gaseous expansion in the ambient zone, and any miners in the neighbourhood of the explosion may suffer from the shock of the impact of the expanded gases and be fatally injured either externally or internally.

8. The expanded gases momentarily increase the density of the air in the mine-workings along which the flame passes. The high velocity of the gases, *plus* the actual pressure due to their expansion, not only increases the density of the air in front of the flame and through which it diffuses,† but the density of the mass of suspended coal-dust, to which is added the dust swept into suspension by the flame from the roof, floor, sides and timbering of the workings, is greatly increased.

9. The result is the almost instantaneous ignition (by the marsh-gas flame) of this suspended coal-dust, and the marsh-gas *plus* coal-dust flame is thus extended until it dies out through the exhaustion of the air, deficiency of coal-dust, change of direction of workings, or the cooling influences of the side-walls.

10. The gases on cooling and contracting, immediately flow back to the source of ignition of the flame and become reheated by the effect of the stored heat in the partially burnt timbering, etc.; and this backward and forward movement adds to the danger of the toxic effects.

11. Coal-dust is in daily use as a fuel for furnace and steam-raising purposes, but its possible effect in extending the area of destruction of a marsh-gas flame was probably first noticed by Michael Faraday, in his youth the assistant and collaborator of Sir Humphrey Davy.

* It is tolerably certain that science and invention will ultimately be able to provide a practicable coal-mine illuminant, which under no conceivable circumstances will ignite a marsh gas and air explosive mixture. We have the basis of such an illuminant in the fact that the brush-discharge of static electricity fails to ignite the most sensitively-explosive mixture; and mercury-vapour or some adaptation of the luminous vacuum-tube may provide the principle of such a desirable and cold illuminant, that will be as incapable of effecting the ignition of marsh gas as is a glowworm.

† The most effective ventilation, as proved by the recent explosion at the Cambrian colliery, fails to remove the danger associated with the presence of marsh gas and coal-dust, even when the coal has a comparatively low proportion of hydrocarbons in its constitution.

12. Prof. W. Galloway has, long ago, proved that the marsh-gas flame is propagated along the workings by coal-dust: the flames travelling along the dusty haulage-roads, which actually contain no trace of the presence of marsh gas.

13. This coal-dust extension of the marsh-gas flame is the principal source of that gaseous element which Dr. Haldane has placed on the highest pedestal as the prime cause of 75 to 92 per cent. of all the deaths resulting from an ordinary coal-mine explosion. This element is carbon monoxide, the highly toxic character of which is now becoming generally recognized.*

14. It is fairly certain that carbon monoxide is not produced in mine explosions by the combustion of marsh gas. The ordinary formula for this reaction is represented by $CH_4 + 2O_2 = CO_2 + 2H_2O$; but the partial oxidation of coal-dust, and even the smouldering timbering of the workings, will produce the toxic gas, thus:—(*a*) $C + O_2 = CO_2$; and (*b*) $CO_2 + C = 2CO$.

15. We can now realize that marsh gas is the igniting-agent of the toxic gas-producer (coal-dust); therefore (neglecting the small proportion produced by the smouldering timber), if this coal-dust were removed from the workings as fast as it is produced, then the toxic dangers to life associated with marsh-gas explosions in coal-mines (dangers which, as we know, are responsible for from 75 to 92 per cent. of the fatalities) would be eliminated.

16. *Coal-dust the Source of the Toxic Danger.*—The famous colliery-expert, John Buddle, as far back as 1813, realized that the major part (he gives the figure as 75 per cent.) of the deaths in colliery-explosions were due to suffocating effects, as distinct from those due to violence.

* The importance of determining the chemical change in the character of the products of the combustion of an explosive mixture of marsh gas and air, and that resulting from the sequential combustion, complete or partial, of coal-dust, will be recognized. The Government would be well advised in appointing a commission of experts to carry out a series of experiments, using, say, an abandoned mine as the scene of the practical determinations, in which coal-dust containing varying proportions of volatile hydrocarbons and of varying conditions of dryness could be laid on the walls, roof, floor and timberings, in as nearly like actual conditions as possible. An explosive mixture of marsh gas and air could be stored in an elastic container, and could be electrically fired at a safe distance. Automatic gas-containers could be located at fixed positions along the line of dust-flame propagation, and so contrived as to catch samples of the products of combustion for subsequent analysis. Such a series of tests would provide valuable indices of the character of the products of combustion and the nature and origin of the flame producing it, and would therefore permit of the origin of the carbon monoxide being carefully traced.

17. In the Tylerstown explosion, 1896, the ratio of fatalities through violence equalled 9·2 per cent., the remainder of the victims succumbing to the toxic influence of carbon-monoxide inhalation (there being 5 deaths by violence, and 51 deaths due to carbon-monoxide toxic effects). The highly toxic (poisonous) character of carbon monoxide will be understood on referring to Table I., taken from the author's paper on "Accidents due to the Asphyxiation of Blast-furnace Workmen."*

TABLE I.—TOXIC EFFECTS OF CARBON MONOXIDE.

Carbon Monoxide in Air. Per Cent.	Time Required to Produce Dangerous Toxic Effects. Hours.	Minutes.	Carbon Monoxide in Air. Per Cent.	Time Required to Produce Dangerous Toxic Effects. Hours.	Minutes.
0·1	2	0	0.6	0	20
0·2	1	0	0·7	0	17
0·3	0	40	0·8	0	15
0·4	0	30	0·9	0	13
0·5	0	24	1·0	0	12

18. It must be obvious that were the coal-dust removed from the workings as fast as produced, and this is quite feasible as will be explained, the deadly virus of coal-mine explosions would be extirpated.

19. It is a remarkable fact that, although coal-dust is the source of the production of the toxic element or carbon monoxide, this same dust is considered to be the true explanation of the comparative immunity of coal-workers from the deadly effects of phthisis.

20. The author, in his investigations in 1880 into the effects of the dust-environment on the health of operatives in various industrial occupations, accepted the accuracy of Dr. Hirts' figures published in 1873 in his work on *Die Krankheiten der Arbeiter*, and tabulated in the author's work on the *Factories and Warehouses: Sanitary and Fire-resisting Arrangements*, published in 1881.

21. The tabulated results show that coal-miners are practically free from dangerous pulmonary diseases, and that charcoal-burners and chimney-sweeps are less liable to phthisis than the workers of all other industries in which dust is produced, and even less than workers in agricultural occupations.

22. *A Coal-dust Environment reduces the Proportion of Coal-miners' Deaths from Phthisis Influences.*—There is little question

* *Journal of the Iron and Steel Institute*, 1905, vol. lxvii., page 395.

but that this remarkable immunity from phthisis is due to the antiseptic effect of the inhalation into the lungs of finely-divided coal (or carbonaceous) dust.

23. This remarkable fact is practically confirmed by the evidence, published by the Government, giving the comparative mortality-proportions from the disease of phthisis in different dust-producing mining operations. Table II. clearly shows the comparison to be strikingly in favour of coal-mine operations.

TABLE II.—THE MORTALITY FROM PHTHISIS OF MINERS, COMPARED WITH ALL OTHER OCCUPATIONS, BETWEEN THE AGES OF 20 AND 55 YEARS.

Tin-miners	65·0 per thousand.
Lead-miners	30·3 ,,
Average of all other occupations ...	20·8 ,,
Coal-miners	15·4 ,,

If those coal-miners, who contract the disease from the deficient ventilation of their homes, were eliminated, the proportion would be still less.

24. The question naturally arises, as to whether the reduction of the proportion of toxic fatalities associated with coal-mining operations, as a result of marsh-gas explosions *plus* coal-dust flame, would be more than counterbalanced by the increase in the number of deaths of coal-miners by the deadly phthisis disease owing to the removal of the antiseptic coal-dust environment.

25. *Coal-dust or no Coal-dust: the Balance of Evil.*—A simple calculation will show, even if we assume that the proportion of coal-miners' deaths from phthisis were increased to that representing the average level of all industrial occupations, that the annual increase in the mortality for each group of 100,000 coal-miners would be no less than 540 men, and in the most effective labour-period limits of 20 to 55 years. This simple figure alone is obviously very much greater than the deaths caused by the toxic evils associated with colliery explosions.

26. *A Partial Removal of the Coal-dust may prove the Best Solution.*—Direct experience will alone determine absolutely how far it is possible to remove the coal-dust without detriment to the healthfulness of coal-miners, and the author suggests that the Government might initiate such an investigation.

27. But, assuming that the coal-dust environment of the coal-miner were permitted to remain as it is, will it be possible to prevent or reduce the deaths from toxic effects?

28. *The Oxygen Toxic Antidote.*—An affirmative answer may at once be given, and for the following reason:—

It is generally known that oxygen is the best antidote for the toxic influence of carbon monoxide. Of course, pure air expels carbon monoxide from the hæmoglobin of blood, but pure oxygen will do the work five times more rapidly.*

29. *The Supply of Oxygen automatically turned on by the Effect of the Explosion.*—Now, if a supply of this vitalizing agent (oxygen) could be established along the line of working operations in a coal-mine, and in such a way that it would automatically escape whenever an explosion of marsh gas occurred, and through nozzles and at different points along which the flame was propagated, setting up at the same time whistling or other audible sounds, so that even in the darkness, which always succeeds an explosion, the victims would readily be able to find their way by creeping or walking to the nozzles of escaping oxygen, the flow of which would continue as long as was required to permit the rescue-party to find the victims and remove them, a duty that would be easily performed, because the location of the danger-zone would be sharply defined by the whistling noise of the escaping oxygen.

30. Assuming that such an automatic and sustained supply of the vitalizing fluid is established in a gassy coal-mine, it is reasonable to imagine that the great majority of the victims, unless crushed by falling timbers, coal, stone or earth, would be rescued from the extreme penalty of toxicity or death. Such a method constitutes the basis of a recent invention, the details of which the author proposes to lay before the members on a future occasion.

* Dr. J. S. Haldane, in his report on the Tylerstown colliery-explosion, made the following statement:—"The blood of a man will take up about 2 pints (1·1 litres) of carbon monoxide or oxygen. Hence, about 1 pint of carbon monoxide must be absorbed to produce half-saturation of the blood. Now, a man at rest breathes about 10 or 12 pints of air in a minute, and experiment shows that of the carbon monoxide inhaled about 60 per cent. is absorbed. Supposing, therefore, that the air contained 0·1 per cent. of carbon monoxide, he would absorb about 0·007 pint per minute. It would thus take him nearly 2¼ hours to absorb a whole pint."

31. It will be readily acknowledged that such a supply of oxygen, or even the automatic tapping of the compressed air from a drill-hose, would take away much of the sting of death of many colliery-explosions; and the necessity of removing the dust will correspond with the proved utility of such a toxic antidote.* But, assuming that it is ultimately decided to remove the coal-dust from all coal-workings, this operation can be easily performed by the application of the mine-dust removal apparatus which is briefly described in the Appendix.

32. *Apparatus to secure the Removal of the Coal-dust.*—The success of this system for removing the dust and gases resulting from blasting operations in metalliferous mines proved its perfect applicability for the purpose of removing the coal-dust in mine-workings, whether the dust is deposited on the floor, roof, timbering or side-walls, or is suspended in the air of the mine-working.

33. Prof. Arnold Lupton, in a letter to the author, strongly suggested the service of this apparatus in coal-mines, because of its portable character and its possible association with the air-compressing gear of the drills, the air-pressure of which can be used not only for driving the suction-fan but also for disturbing dust-deposits for which the suction-mounting is inapplicable. The separation of the dust and certain noxious gases is effected by the principle adopted in the author's method of purifying blast-furnace gas. The mine-air would not only be separated from its suspended constituent, but it would be introduced into the workings in a slightly moist and comparatively pure condition.

34. The method of damping the coal-dust by water-sprinkling will obviously tend to reduce the proportion of dust that would be blown into suspension by the effect of an explosion; but unfortunately the presence of accumulations of water on the floors of workings has been known to introduce the danger of ankylostomiasis, and liability to contract rheumatic ailments is also known to be associated with the presence of water. Of course, the ventilating air in gassy mines could be moistened after the fashion adopted in factory-ventilation, examples of

* The perfection of portable oxygen-containers, available as they are at reasonable cost, makes the deficiency of such a provision for a rescue-party in any coal-mine an unpardonable omission.

which can be found in the author's book on *Factory Sanitation*. The system of mine-air purification, described in the Appendix, will obviously tend to moisten the air.

35. *Conclusion.*—The writer may now summarize the advantages and disadvantages of permitting the dust to remain as at present, but with a complete oxygen-supply equipment; the dry system of removing the coal-dust; and the water-sprinkling system of settling the dust:—

(I.) Dry system of removal:—

Advantages: the reduction of the extent of the flame-propagation through the influence of the presence of coal-dust, and the lessened danger of asphyxiation by carbon monoxide.

Disadvantage: liability of increase in the proportion of miners' deaths from phthisis.

(II.) Use of water-sprinkling for settling the dust:—

Advantages: the reduction of the extent of the marsh-gas and coal-dust flame-propagation, and, consequently, lessened danger of asphyxiation or toxic effects.

Disadvantages: liability of increase of miners' deaths from phthisis; and miners may contract ankylostomiasis and rheumatic ailments.

(III.) Allowing dust to remain as it is, but providing a complete equipment for oxygen-supply:—

Advantages: reduction in the proportion of deaths from toxic effects; mortality from phthisis not increased; and no danger of contracting ankylostomiasis or rheumatic ailments, in addition to present liabilities.

Disadvantages: no decrease in the flame from explosion due to the presence of the coal-dust; and the miners are still subject to danger from the inhalation of carbon monoxide.

36. The author trusts that this brief review of the conditions that on the one hand endanger, and on the other hand safeguard, the life of a coal-miner may be accurately balanced; and that the weight of evidence in the direction of precautionary reform will bear effective and early fruit for the benefit of the workers in the great and national industry of coal-getting.

APPENDIX.—Description of Coal and other Mine-dust Removal-Apparatus.

British patent, 1904, *No.* 13,594. *Improvements in Apparatus for Dealing with Dust in Mines and the like.* Messrs. B. H. Thwaite, T. J. Denny and R. E. Commans. This invention relates to an improved method of separating from the air of mines in or near the working-face, the siliceous and other mineral and carbonaceous dust resulting from the drilling and ore-getting operations, as well as the objectionable elements of the productions of combustion of the high explosives used in mining operations.

The air is collected by powerful suction from as near the points of emission of the dust from the drill-hole as possible, the collecting pipes being so devised as to allow them to be rapidly applied by screw-adjustments to any position at the face or across the drive, with as little interference with working operations as practicable. The dust-laden-air collecting pipe is perforated on its under side, and may be provided with sliding sleeves to cut off some of the perforations; or the perforated pipe may be bent, so that it will more effectively remove the air from the locality of emission or of production. This portable dust-collecting pipe is made of suitable metal, light but rigid, and not easily damageable by falling rock or explosive effects. At the end of the collecting pipe, a branch-swivel or other rapidly-applied attachment is provided, so that a flexible pipe, such as an armoured hose, can be easily connected to it in such a way as not to obstruct working arrangements.

The armoured hose delivers the dust- and gas-charged air to the portable purifying apparatus, which consists essentially of three elements:—(1) the washer; (2) the compound fan or suction-apparatus; and (3) a slag-wool or sawdust filter. The washer consists of a vessel containing water, or water to which quicklime has been added, and to which a disinfectant or deodorizer can also be added. By an arrangement of partition-plates and baffle-plates (either straight or circular, depending upon the shape of the vessel, and from which are suspended perforated plates or wire-netting or gauze, with the object of compelling the air-flow to be of uniform character), the air is compelled to flow repeatedly through the water, and several times in succession. If the water is charged with quicklime, the carbon dioxide present in the air will be immediately absorbed, and if the water contain a disinfectant any germs carried with the air will be attacked.

After being drawn through the washing or water-filtering apparatus, the air enters the compound fan, which may also in certain applications be equipped with water-jet pipes, to assist in separating the dust by centrifugal effect. The fan is of the enclosed type, and is so constructed as to establish easily a suction-effect equivalent to a head of several inches of water. In order to enable the water, separated by the effect of centrifugal action, to flow from the fan into the washer, the fan may be placed at such an elevation as to permit of this. The purified air, in flowing from the fan, enters an armoured hose-pipe, conveying it to a distributing pipe, which, like the collecting one, is easily fixed to secure the best results, the air, of course, being delivered as near where the men are working as is practicable. For special applications, a slag-wool or wood-wool filter may be added, through which the air is forced by the fan.

Fig. 1 (Plate X.) shows the general arrangement of the apparatus in its application to a drift in a mine, in which drilling and blasting operations are being performed. The dust from the different drills is drawn away by the sucker-hood or terminal, A, held in position by the supporting and adjust-

able crutch, B. The dust is sucked through the branch-pipes, D, which are preferably armoured. The particles of dust that may be sucked into the hood, A, are carried along for some distance until they reach the coupling, E, which can be rapidly disconnected. The dust is sucked forward to the dust-collector, F, by the powerful aspiratory influence of the centrifugal fan, G. The dust-collector, F, described in greater detail in Fig. 2, is placed in a cavity, or in any other position removed from a point of interference in the active operations of drilling, blasting and transportation. A perforated pipe, H, spans the drift near the zone of drilling operations, so that when blasting is being carried on, the suction-effect of the centrifugal fan, G, connected to the cross-pipe, H, rapidly clears away the products of the blasting operations. The products of combustion are forced through the absorbing and cleansing fluid in the collector-vessel, F. One main pipe, C, is available for several drills and cross-pipe requirements.

Fig. 2 (Plate X.) represents a longitudinal section of the dust-collector vessel, with its associated centrifugal fan and electric motor for driving the same. The dust-collector, F, consists of a rectangular vessel, containing the absorbent and filtration-liquid, the level of which is maintained at *a*. Through this liquid, the gases and the air carrying the dust in suspension are forced to flow in thin streams, because the volume of air is broken up by the hanging perforated plates or wire-gauze frames, *b*. Other plates, *c*, divert the flow of the air. The dust-collector, F, is equipped with a liquid-seal compartment, *d*, formed by means of a sloped or inclined plate, *e*. This arrangement enables the miners to notice the height, muddiness and colour of the liquid; it allows of new absorbents, or other chemical agents, as well as water, being added, and the deposited dust can be raked out of the vessel without stopping its operation. The dust-collector, F, is fitted with flanged wheels, *f*, so that it can be run on the mine tram-rails, *h*. It is placed on a framed mobile-carriage, *i*, that carries the centrifugal fan, G, and its electric motor, I. The dust-collector, F, may, moreover, be so arranged in relation to its carriage, *i*, that it can be tilted in such a way as to reduce the depth or degree of the hydraulic seals formed by the partitions, *b* and *c*: that is, when the apparatus is being used for the removal of the products of combustion after blasting operations. The carriage-frame, *i*, is mounted on rollers. The pipe-connections, *j*, deliver the air, gases and dust into the collector-vessel, F, and the cleansed air passes into the fan by the pipe-connection, *k*. The arrows indicate the direction of the flow of the air and the dust, which it contains in suspension.

Fig. 3 (Plate X.) is a detailed plan of the sucker-hood or terminal, by which the dust is drawn into the hose from the drill-holes. The sucker-terminal, A, (Fig. 1, Plate X.) is made of light sheet-steel or aluminium. When special suction-effects are required, an elastic collar, *o*, made of spongy indiarubber, is provided. The suction-effect is applied by the annular orifice of the collar, *o*. This sucker-hood surrounds the drill-bar, *m*; a gap allows of the sucker-hood being readily applied, but, of course, the sucker or hood may be made completely circular. The elastic collar, *o*, is riveted to the plate-sides of the annular grove or trough, *p*.

Fig. 4 (Plate X.) shows the special kind of air-main coupling that may be used to retain such particles of stone or pebbles as may have been sucked into the air-main. This coupling can be readily disconnected, and a coarse wire-gauze screen, *q*, may be placed across the coupling-area.

Mr. CHARLES PILKINGTON said that, so far as the removal of coal-dust was concerned, it would, if possible, be better to prevent its accumulation in large quantities. At the Pendlebury collieries, the coal produced a large amount of dust; but, as steel-tubs were used that did not leak, the bulk of the dust, which would otherwise have been deposited on the roads of the mine, was taken to bank. There were always objections to every scientific invention that had been brought out, and he suggested that the liberation of oxygen might tend to produce fires, with disastrous results.

Mr. HENRY HALL (H.M. Inspector of Mines) said that the author suggested that the toxic effects of an explosion could be obviated by providing a system of pipes containing oxygen. In the event of an explosion, however, these pipes would be destroyed, and the oxygen would all be lost at one point and not distributed throughout the workings as the author imagined. As regarded the dust, he would encourage Mr. Thwaite to this extent, that there was not the slightest chance of introducing any system that would reduce the dust to such a degree that it would cause miners to suffer from phthisis. The removal of dust was a difficult operation; and if the writer suggested a dust-collector, similar to that employed to clean houses, he would recommend him to visit a dusty coal-mine, and he would then realize that no appliance of that kind could possibly remove the accumulated volumes of dust.

Mr. W. H. COLEMAN said that carbon monoxide could only be produced from carbon dioxide by reduction by coal-dust at a temperature considerably higher than would be found in a coal-mine. Possibly it might be formed from marsh gas or fire-damp, when an explosion was nearly finished and the proportion of the air was diminished. He did not think that the removal of the coal-dust would decrease the production of carbon monoxide.

Mr. W. N. ATKINSON (H.M. Inspector of Mines) said that it had been proved that carbon monoxide was formed by the ignition of coal-dust in the complete absence of fire-damp. With reference to Mr. Thwaite's proposal to take oxygen in pipes into the mine for use after an explosion, it was extraordinary how great a fascination a series of pipes seemed to have for persons

not intimately acquainted with the working of mines. He thought that the general lack of success of all such schemes did not say much for the equipment for the supply of oxygen; but he thought that the apparatus for removing the dust by pneumatic means was well worthy of investigation. Despite the immense amount of dust on a colliery-road, it was only a matter of providing sufficient tubs for its removal, if it could be collected and drawn into them; it was simply a question of the apparatus, and whether it could be applied on a large enough scale. An apparatus that would clean a road absolutely, by removing all the dust, would be of the greatest use.

Mr. C. C. LEACH said that the cost of removing the dust by such an appliance would be considerable; and if the cost of carpet-cleaning was any criterion, the cost of the removal of dust from a coal-mine would be prohibitive.

Prof. HENRY LOUIS believed that the views of the previous speakers were practically correct, and that coal-dust, burned with an insufficient supply of air, would produce carbon monoxide; but, the reaction indicated by the second equation* could not occur at the temperature ordinarily obtainable in colliery-explosions. He agreed with Mr. Hall that the pipes, containing the oxygen, would be wrecked by an explosion, and the survivors would see a fine exhibition of fireworks. With regard to the question as to whether coal-dust prevented phthisis or not, there was surely something more to be said. A comparison had been drawn of the small amount of phthisis among coal-miners as compared with metal-miners; but the conditions of working were very different, quite apart from the fact that the coal-miner was wound up from his work in a cage, while the metal-miner had frequently to climb a considerable length of ladders in shafts, which in itself was proved to have a very serious effect. In any case, the cost of Mr. Thwaite's appliances would be prohibitive.

Mr. J. S. MARTIN (H.M. Inspector of Mines) said that the proposal to carry oxygen in pipes into the mine reminded him of a similar suggestion that had been made for the erection of refuge-holes, which were to be supplied with fresh air by means of pipes. This arrangement had been adopted in one mine, and

* *Trans. Inst. M. E.*, 1905, vol. xxx., page 391.

on one occasion, when visitors were shown the arrangement, it was found that the refuge-hole, fitted with doors, etc. (where the miners were to go for safety after an explosion) was full of fire-damp: it had been erected over the orifice of a blower of gas. He was afraid that the use of pipes, in the way suggested, would not be practicable. He asked, with regard to the supply of oxygen, whether Mr. Thwaite had calculated the quantity that would have to be supplied, and the cost of the apparatus required to provide the necessary quantity.

Dr. F. C. GARRETT (Armstrong College) wrote that Mr. Thwaite's statement that "It is fairly certain that carbon monoxide is not produced in mine explosions by the combustion of marsh gas"* required qualification. More than a century ago, John Dalton found that when marsh gas was exploded with its own volume of oxygen (half the amount required for complete combustion), it gave equal volumes of steam, carbon monoxide and hydrogen; and his results have been confirmed by Messrs. Kersten, E. von Meyer, J. W. Thomas and others.† Mr. Thwaite appeared to suggest that, after an explosion, oxygen should be admitted into the workings in sufficient quantity to enrich the air, and that this supply should be kept up "as long as was required to permit the rescue-party to find the victims and remove them";‡ this would, of course, necessitate the blowing in of enormous volumes of oxygen, and would very greatly increase the risk of fire.

Mr. M. H. HABERSHON wrote that it would be impossible to reproduce experimentally the dust-conditions existing in many coal-mines. He thought that any series of experiments, such as were suggested by the writer of the paper, would be of no practical value at the present time. The explosive nature of coal-dust was fully recognized. The danger was a very real one; its causes and the possible methods of removal had been recently summarized in an admirable paper by Mr. W. H. Pickering, H.M. inspector of mines (India).§ The administration of oxygen was doubtless the best method of dealing with carbon-

* *Trans. Inst. M. E.*, 1905, vol. xxx., page 391.

† The subject was discussed in *A Treatise on Coal, Mine-gases and Ventilation*, by Mr. J. W. Thomas, London, 1878, pages 154 and 323.

‡ *Trans. Inst. M. E.*, 1905, vol. xxx., page 394.

§ *Ibid.*, 1905, vol. xxix., page 134.

monoxide poisoning, but any suggestion involving the laying of pipes along the roadways of a mine for this purpose could only be considered as impracticable. He thought that the loss of life, from this cause, in mines, could only be reduced by training men in the use of the pneumatophore; as by this means oxygen might be administered, and lives saved. The pneumatophore was gradually being improved, and in its present form was a very different apparatus from that originally tried in this country. He thought that suitable men, thoroughly trained, would be found capable of accomplishing far more in the work of exploration, rescue and restoration of a mine, than was generally thought possible by those unfamiliar with the latest type of this apparatus. It would, however, be useless to provide apparatus without taking steps to keep it always in the most perfect order and having men at hand thoroughly trained and in practice. He thought that the establishment, by groups of neighbouring collieries, of central stations with this object, would be found preferable to individual effort; and that there was no subject at the present time more deserving of the consideration of The Institution of Mining Engineers.

Mr. H. Richardson Hewitt (H.M. Inspector of Mines) wrote that Mr. Thwaite's paper was of a somewhat remarkable and unusual character, and appeared to imply that the remedy for explosions of fire-damp in mines was quite simple. There could be no doubt that coal-dust played a great part in explosions, and even if it were possible to clear all roadways of dust during one day, sufficient would be made during the next twenty-four hours to render the continuation and extension of a fire-damp explosion possible, assuming that coal had been conveyed along the roads. It was not the huge amount of dust lying on the floor which was immediately dangerous, but the extremely fine particles which were floating in the atmosphere of the mine, and gave an underground traveller a black face without his appreciating the fact from his own feelings. The dust on the floor only served as a creator of the fine particles by the disintegration which it was undergoing from the traffic passing along. The proposed apparatus for removing dust seemed to apply only to the particles caused by the boring of shot-holes, which were of no importance whatever in a coal-mine; but not to the dust

caused by the conveyance of coal along the roadways, which was produced in immense volumes. If it were possible to apply this arrangement to the roads, it would be a similar appliance, on a large scale, to the vacuum-appliances that take the dust out of household-carpets without removing them from the room in which they are laid down. The appliance is successful on a small scale, but it appears to be an impossible arrangement for use in cleaning a large mine in a similar manner. Mr. Thwaite suggested that a supply of oxygen should be liberated by the force of the explosion; but surely such an arrangement would only increase the devastation originally caused by extending the area of damage, and would be the means of setting fire to all combustible material and burning the workmen in the mine, as well as extending the fire to the surface-buildings. The sugggested remedy appeared to be worse than the original catastrophe.

The PRESIDENT (Sir Lees Knowles, Bart.) moved a vote of thanks to Mr. Thwaite for his interesting paper.

Mr. H. HALL seconded the resolution, which was cordially approved.

Mr. S. F. WALKER read the following paper on "Earth in Collieries," etc.:—

EARTH IN COLLIERIES, WITH REFERENCE TO THE "SPECIAL RULES FOR THE INSTALLATION AND USE OF ELECTRICITY."

By SYDNEY F. WALKER.

Introduction.

The writer has attached, as an appendix to this paper, so much of the "Special Rules for the Installation and Use of Electricity" as refer directly to connections to "earth."

Three points appear to be evident from these Special Rules:—(1) The object of the Departmental Committee, in all the Special Rules, is to minimize the danger of shock, and of fire, but principally of shock. (2) They wished to keep "earth" completely out of any electric system in use in collieries. And (3) they wished to ensure that, under no circumstances, could anyone about the mine place himself in such a position that a dangerous current could pass through him; or, in other words, that no dangerous pressure should exist between the ground, floor, etc., that men about the mine must stand on, and any object they might touch. The writer proposes to discuss the question as to how far the objects of the Departmental Committee have been or are likely to be accomplished by the working of the Special Rules.

What is Earth?—Perhaps it may be as well to clear the ground a little, by enquiring what is meant by "earth?" The term has come down to us from the very early days of electricity, when it was supposed that "the Earth" was an infinite reservoir of electricity, into which any quantity of current might be passed, and from which any quantity might be called up; that it bore the same relation to the electric currents used, as the mass of the ocean bears to the water used for domestic purposes; and in those days the idea was not very inaccurate. Earth, in those days, performed the useful office of a return-wire for telegraph-currents, and it really did not matter whether

the Earth acted as a reservoir, or whether the currents actually passed through the Earth's crust; and whether any portion of, say, the return-current from Manchester to London passed by way of Glasgow or not. With the development of electrical engineering, however, the whole problem has changed. Telegraph-engineers discovered, many years back, that the Earth had resistance, and that in some localities the resistance was so high that earth could not be used as a return, in the ordinary way. And gradually the proper knowledge of the matter has been worked out, that the Earth's crust is a conductor, just as other bodies are; or it would be more correct to say that it conducts, when sufficient pressure is applied to points at its surface to overcome its resistance, again just as any other body. Every substance forming the Earth's crust has its own resistance, and will conduct strictly in accordance with the laws of electricity as they apply to other bodies; and this applies as fully to the substances in and about a coal-mine, as to other parts of the Earth's crust.

In all parts of the Earth's crust, there are two substances which are largely engaged mainly in conducting any electric currents that are passing through the Earth's crust, that form a large percentage of the effective path through it, metals that are laid in or on the surface, and water, often impregnated with mineral salts, held in the pores of the strata. But every substance, whether porous or not, and whether it carries moisture or not, has its own resistance, and will conduct strictly in an inverse ratio to that resistance, and directly as the nett pressure available to drive currents through it. Water-pipes, tram-rails and wire-ropes, will play an important part in coal-mines in the conduction of any currents that are delivered to earth, but the strata themselves will also perform their share, strictly in inverse proportion to their resistances.

In this connection, the measurements recently taken by Mr. G. C. Wood,* under the supervision of Prof. H. Stroud at the Armstrong College, Newcastle-upon-Tyne, are of the very highest importance. From a perusal of Mr. Wood's paper it will be seen that coal has a very high resistance, bearing comparison, in fact, with some of the substances employed for insulation; and it follows that any conduction that takes place must be, for

* *Trans. Inst. M. E.*, 1905, vol. xxx., page 99.

practical purposes, by the tram-rails, water-pipes (where they are present) and wire-ropes, assisted, as far as they can be assisted, by the "thill," this having an enormously lower resistance than the coal.

Protection from Shock.—In the great majority of cases, a man receives a shock in a coal-mine, because his feet, being already in connection with a conductor, his hands, his body or his head make contact with another conductor, between which and the one he is standing on, there exists a sufficient electrical pressure to drive a dangerous current through him. Protection means then, so arranging that he cannot, wherever he may be standing, in or about the mine, come into contact with any conductor at more than a few volts difference of pressure from the ground, floor, or whatever he may be standing on. There are two methods of accomplishing this, both of which are made use of in the Special Rules.

A large portion of the possibly available pressure may be used up by the interposition of a high resistance in the path of the current through the man, and this method is adopted in the Special Rules* quoted for protection at the switchboard where either gloves, mats or insulated floors are to be provided. It can also be accomplished by lowering the available pressure at all points where shocks can be obtained, and this is the method commended by the Departmental Committee in the Special Rules† referring to earthing. In all of them, the idea is, that all metallic surfaces that anyone can possibly touch shall be placed at a very low difference of pressure from the ground, etc., upon which everyone about a mine must stand. All metallic surfaces that it is possible to touch are to be brought to such a condition electrically, that the difference of pressure, between them and the ground on which men about the mine must stand, is reduced to very small figures, say less than 50 volts: this being accomplished by armouring all cables, or enclosing them in pipes; enclosing all switches; and earthing all armour, pipes, frames of machines, cases enclosing switches, etc.

And here comes in the question, what do we mean by connecting to earth in this matter? Broadly speaking, the coal-mines

* Section I., No. 10; and Section II., No. 5.

† Section I., Nos. 1, 2, 3 and 5; Section II., No. 6; Section III., Nos. 1 and 2; and Section VII., No. 2.

in this country may be divided into two classes, for this purpose, those in which there is water in the workings, with pumps and water-pipes leading from the pumps to the shafts; and those in which there is none. In the former set of collieries, earth means the water-pipes, *plus* the tram-rails, and the strata on which they are laid; and efficient earth means good electrical connection between the water-pipes, and the ground upon which men may be standing when they may grasp a cable, or other conductor; and good electrical connection between armour, etc., and the water-pipes. As there is usually a good deal of water on the roads, when there is water in-bye, the connection between the water-pipes and the floor of the roads is sufficiently good to call the latter "good earth," for all currents of moderate strength; and, therefore, so far as protection is afforded by connecting to earth it is obtained in these collieries with currents of moderate strength. But it is a very doubtful matter, if protection is obtained by connection to earth, in this way, where earth is of the best of its kind.

It is somewhat erroneously supposed that connecting two conductors together puts them at the same pressure, and neutralizes any difference of pressure that exists between them. The same idea prevailed in the early days of electric lighting, when it was proposed to connect two or more generators in parallel. It was gravely stated that the mere connection of the plus poles of two dynamos together, and the minus poles together, rendered the pressures delivered by the two machines the same, without taking any other measures to equalize them; and a large number of apparently mysterious burnt-out armatures was the result. Two or more dynamos can be run together in parallel, provided that the precaution is taken of making the pressures which each delivers at the point of common connection, the omnibus-bars, equal; but the mere connection of the terminals together does not render the pressures equal. What is done in such a case is to provide an additional path for a current, through one or more of the dynamos, due to the difference in the pressure generated by the individual dynamos. It may happen that the machines connected together deliver the same pressure, but more frequently they do not, and each of them takes the whole load, *plus* that offered by the additional path through the other machines, in turn, instead of its being divided between the whole of the machines running.

The writer has mentioned this case, as one instance of the fallacious ideas that have prevailed from time to time. Paralleling of dynamos is now carried out by equalising the pressures before connecting them. Similarly, if two cables are armoured, the armour being earthed efficiently, and if the insulation of one of them breaks down, the armour becoming alive, the pressure in the conductor that has broken down is not thereby neutralized: only an important portion of the resistance from one path, the path through the insulation, that is open to the pressure of the service, is removed. And, though nothing may happen immediately, conditions may easily arise in which a dangerous pressure may exist between some metal that a man can touch and the floor upon which he is standing; and that not only despite the presence of the efficiently earthed armour, but in consequence of it, if the insulation of one cable has broken down. So long as the insulation is perfect, all will be well, but immediately one armour becomes alive, a totally different set of conditions is produced, the full scope of which it is difficult to forecast. There would be differences of pressure between the armour on different parts of the cable; and, although these may not be great at first, when things are comparatively new, the constant changes, the constant deteriorations that are going on, may produce the very difference of pressure which it is the object of the Departmental Committee to avoid.

It appears to the writer that if earth is to be admitted into the system, by far the best plan would be to adopt the system of concentric uninsulated return. With that there is no question of obtaining good earth; the return-path is necessarily perfect, or the system cannot work. This system can be applied to three-phase, as well as to continuous, current.

The Special Rule, quoted from Section VI., affords a striking commentary on the whole question. If electric locomotives are established in coal-mines in this country, and earth be permitted on the power-supply system, the currents will find their way from the locomotive system to the power-system and *vice versa*, no matter how carefully the two are separated, if the insulation of either supply-cable breaks down.

It should be remarked also, that leaving out other matters, earthing any part of any system increases the probability of shock to attendants who have to trim brushes, see to fuses, etc.,

and this particularly applies to earthing the neutral wire of polyphase systems, etc.

Earth: where there is no Water inbye.—In the foregoing paragraphs, the writer has dealt with the most favourable conditions for obtaining earth; but, where there is no water in the workings, and where the mine is dry and dusty, it will be found very difficult to obtain earth at all. Earth, to be efficient, must be of sufficiently low resistance to make very little charge upon any pressure delivered to it, in other words, to allow the passage of currents freely through it. According to the measurements referred to above, by Mr. Wood, the resistance of coal ranges from 33,000 million to 80,000 million ohms as against copper, 0·001,59 ohm; while contact with the coal would be very difficult to obtain, and would add to its resistance. The resistance of the underlying stratum, the thill or floor, is very much less, ranging according to Mr. Wood's measurements from 13,000 to 105,000 ohms. According to the measurement of Mr. W. Moon, of the Postal Telegraph Engineers' Department,* the resistance of some clays is less, ranging from 2,500 to 23,500 ohms, when mixed with sand and gravel.

Apparently, the only possible earth obtainable is by connection to the floor, and the actual earth-path will be by way of the tram-rails *plus* the floor itself. It will be, therefore, interesting to see what the resistance of the possible earth-path is likely to be in these collieries. In cases of this kind, it will be evident that it is the worst case that must be provided for, the case where the resistance is highest. The resistance offered by the earth-path will be made up of two quantities, the resistance of the strata which form the path, that of the tram-rails which assist it, and that of the connections between the tram-rails, and other metal used and the strata. Connections to earth are proverbially difficult to arrange, except in the case where two metal-plates can be immersed in a body of water, common to both ends of the circuit, or to two bodies of water connected by other bodies of water of large volume. The resistance of the connection between the plates used as earth-plates and the earth follows the same law as other resistances: it varies inversely as the sectional area of the strata embraced by the plate, or whatever is making the

* "Earth Connections," *The Electrical Review*, London, 1904, vol. liv., pages 485 and 526.

connection. But this is varied by the fact that the current itself, in its passage, creates an opposing pressure at the surface of the plate, which, by reducing the available pressure, practically increases the resistance; and this polarization, as electrical engineers call it, is approximately proportional to the strength of the current passing across the junction. The resistance opposed to the passage of the current, at the junction with the strata, will depend also upon the substance that is employed. Metals offer the least resistance, other things being the same, as in all other cases; and wood will offer a high resistance, especially where there is coal-dust between it and the floor.

The resistance of the stratum forming the floor or thill varies directly as the length of the stratum through which the current passes, and inversely as the sectional area. That is to say, the farther inbye that the earth-connection is required, the greater will be the resistance offered to the passage of current through the floor, and the thicker the stratum, the lower will be its resistance. The resistance of a very thin floor will be very high, unless there is a stratum underlying it, with which it is making good electrical connection, and which is of a comparatively low resistance. Faulting of the strata will also play a very important part in this matter, as the effective area of the floor available for the conduction of currents passing in the earth-path, will be bounded by faults, for practical purposes. The stratum against which the floor abuts at a fault may be fairly conductive, but there will always be introduced into the earth-path a considerable additional resistance, owing to the passage of the current from one stratum to the other.

As to the probable resistance of such an earth-path, the writer has worked out the following formula for the resistance of the path formed by the strata alone, which it will probably be safer to assume as the path to be used for calculations:—$R = SL \div WT$: R being the resistance of the stratum between the point that is to be connected to earth, and the nearest point where really good earth can be obtained; S, the specific resistance per cubic inch of the floor, or whatever the stratum may be, that forms the earth-path; L, the distance in yards between the point where good earth may be obtained, and the farthest point where it is wanted; W, the width in yards of the underlying stratum between faults; and T, the thickness of the same in

inches. By specific resistance per cubic inch is meant the resistance between opposed faces of a cube, 1 inch on the side. The measurements made by Mr. Wood and by Mr. Moon, were per cubic centimetre, as is usual in laboratory-work. The writer has converted the figures to per cubic inch in order to simplify the calculation, since all other measurements are in inches, feet or yards.

Taking the specific resistance per cubic centimetre of the floor as 10,000 ohms; this is probably a low figure (Mr. Wood's lowest is 13,000 ohms), and equals approximately 4,000 ohms per cubic inch; and taking a thickness of floor of 1 foot, and a width between faults of ½ mile, the writer makes the resistance for a length of 1 mile of the stratum, between the inbye-point where good earth is obtainable, 666 ohms; for 2 miles, 1,333 ohms; and for ½ mile, 333 ohms. With a width of 1 mile between faults, the thickness being the same, the writer makes the resistance for 1 mile, 333 ohms; for 2 miles, 666 ohms; and for ½ mile, 166½ ohms. With the last values, if the thickness of the stratum is only 6 inches, the resistance becomes again 666, 1,333 and 333 ohms respectively, and the other values are in proportion. The above results are given, merely to show what the resistances are likely to be. There is the conductive path offered by the tram-rails, but the writer fears that this will not reduce the resistances very much. There is the contact-resistances between each rail and the sleepers upon which it rests, and between the sleepers and the floor, and both of these will be high, while there will be very little assistance from the continuity of the rails. If half the total resistances, as given above, or as deduced from the formula, are taken, as the result of the combined paths of the floor and the rails, probably the calculation will be more favourable than actual experience would warrant.

The matter is one for actual measurement, and the writer understands that further measurements are to be made at the Armstrong College on contact-resistances. Meanwhile, there is sufficient information at hand to say that the probable resistances of earth-paths in dry and dusty mines will be absolutely prohibitive. To be efficient, the total possible resistance of an earth-path that is to be capable of protecting on all possible occasions, should not exceed a small fraction of an ohm. The office of the earth-path, if it is to accomplish the object assigned

to it by the Departmental Committee, is to neutralize all but very low pressures, under all possible conditions, and this can only be done, if at all, with the large currents that will be used, or that may have to be accommodated in the process, by a path of very low resistance. As mentioned above, if earth is to be admitted into the system, there is only one method of accomplishing what the Departmental Committee desire, that is, by using the plan adopted by Messrs. Mavor & Coulson of an uninsulated return, completely enclosing the live conductor. This plan can be arranged with three-phase by making one of the three conductors the uninsulated return, the equivalent of the arrangement on the railways using three-phase currents, the currents being delivered to the trains from two overhead wires, the rails being the equivalent of the third wire.

In the foregoing section, the writer has had in his mind, principally, the question of protection from shock, but the question of protection from fire is quite as important, and for that "earthing" at its best appears to him to be attended with very great risks, on account of the large currents, often leading to sparking, and to arcing that may have to pass by way of earth.

Apparatus for Recording Leakage.—Several appliances have been placed on the market, since these Special Rules were promulgated, designed to accomplish the object set out in the seventh Special Rule of Section I., all being based on the same general principles. Earth may be taken to be a conductor with which either conductor of a supply-service may, and does, at times, become more or less in connection, and the amount of the connection that either has made will be indicated by the current passing between the other conductor and earth, when the other conductor is also connected with earth through an instrument that will denote the passage of leakage-currents. Normally, the two conductors of a two-wire service, or the three conductors of a three-phase service, are separated electrically by the resistance of the insulating envelopes of the two cables, *plus* any resistance that may be present between the exteriors of the cables. If one cable is directly connected to the common conductor, the earth, half the resistance between the two has been removed; and if either is connected in a smaller degree, speaking in the conductive sense, that portion of the total resistance will have been removed.

In all the instruments on the market, the resistances of the insulating envelopes of the cables are represented by artificial resistances, equal in value, and both large: one end of each resistance being connected to one of the supply-cables and the two resistances connected together at their ends, and the junction connected to earth, a very low-reading ampère-meter being inserted between the junction and earth. If the insulation-resistance of either cable is lessened, the artificial resistance on that side is more or less bridged, or shunted, and the pressure between the opposite cable and earth is increased, with the result that a current passes through the instrument which measures, in certain units (that can be determined by experiment, and are known to the designer), the leakage or the loss of resistance on the other side. When the insulation of both cables is perfect, the pressure at the junction between the two resistances should be *zero*, the supposed pressure of earth, and therefore no current passes through the instrument. As the insulation-resistance of one cable falls, the pressure between the junction and the opposite cable rises, the current which it causes to pass through the measuring instrument being a measure of the fall of resistance of the faulty cable. If the insulation-resistance of both cables falls equally, the instrument does not register the fact, because the point of junction remains the hypothetical *zero*, but any difference in the fall of insulation of the two is registered. To meet these cases, all the appliances on the market are provided with switches on each leg of the artificial resistance, enabling either of them to be disconnected at will. Breaking the circuit of one resistance leaves the connection between the cable with which it is connected and earth still existing; and the amount, it is claimed, is read off in the deflection of the needle due to the current passing through the coil from the opposite cable.

For three-phase working, each cable has its resistance, the three being connected together at one of their ends, and through an ampère-meter to earth. As before, any fall of insulation-resistance is shown by the deflection of the needle, and the fall on each cable is shown by disconnecting it from its resistance. It only requires a simple addition to either apparatus to provide for giving an alarm when a certain minimum-resistance from earth is reached, by ringing a bell, or lighting a lamp.

The early lamp earth-signals, originally introduced by Mr.

Thomas Alva Edison, the writer believes, in connection with a town-supply service, are still sometimes used for that purpose, and are on the same lines as the apparatus described above. Two lamps, arranged for the full pressure of the service, were bridged between the two mains, the junction between the lamps being connected to earth. As long as all was right, the lamps burnt very dimly, but as the insulation-resistance of one main fell, the lamp connected to the opposite main grew brighter, and if either main was making dead earth, the other lighted up to its full power. The lamps were coloured red and green, as a guide to the attendant.

Regarding all these appliances, it must be understood that for them to be effective, earth must really and truly be represented by a conductive path of very low resistance. With such a path, as has been calculated above, in dry and dusty mines, the apparatus would only work, if the cable made actual connection with the metal that was used for earth. If earth were made in the sump, or the mass of the engine at the engine-room, or the equivalent at the pit-bottom, and a cable rested bare for several feet on the ground inbye, there would rarely be any indication on either the lamps or the ampère-meter.

APPENDIX I.—Special Rules referring directly to Connections to Earth.

Section I.—General.

Rule 1.—(c) All metallic coverings, armouring of cables, other than trailing cables, and the frames and bedplates of generators, transformers, and motors other than portable motors shall, as far as is reasonably practicable, be efficiently earthed where the pressure at the terminals where the electricity is used exceeds the limits of low pressure [250 volts].

Rule 2.—Where a medium-pressure supply is used for power-purposes, or for arc-lamps in series, the wires or conductors forming the connections to the motors, transformers, arc-lamps, or otherwise in connection with the supply, shall be, as far as is reasonably practicable, completely enclosed in strong armouring or metal-casing efficiently connected with earth, ...

Rule 3.—Where a medium-pressure supply is used for incandescent lamps in series the wires or conductors forming connections to the incandescent lamps, or otherwise in connection with the supply, shall be, as far as is reasonably practicable, completely enclosed in strong armouring or metal-casing efficiently connected with earth, ...

Rule 5.— . . . . the wires or conductors other than overhead lines aboveground forming the connections to the motors or transformers or otherwise in connection with the supply shall be completely enclosed in a strong armouring or metal-casing efficiently connected with earth, or . . . .

SECTION II.—GENERATING-STATIONS AND MACHINE-ROOMS.

Rule 6.—All terminals and live metal on machines over medium pressure aboveground, and over low pressure underground, where practicable shall be protected with insulating covers or with metal-covers connected to earth.

SECTION III.—CABLES.

Rule 1.—All conductors (except as hereinafter provided) shall in every case be maintained completely insulated from earth, but it is permissible to use the concentric system with earthed outer conductor, if proper arrangements are made to reduce the danger from fire or shock to the minimum, but the neutral point of polyphase systems and the middle wire of three-wire continuous-current systems may be earthed at one point.

Rule 2.— . . . . Where lead-covered cable is used the lead shall be earthed, and electrically continuous throughout.

SECTION VII.—ELECTRIC LIGHTING.

Rule 2.—Small wires for lighting-circuits must be either conveyed in pipes or casings, ... If metallic pipes are used they must be electrically continuous and earthed. . . .

APPENDIX II.—ADDITIONAL SPECIAL RULES BEARING UPON THE SUBJECT.

SECTION I.—GENERAL.

Rule 1.—(*a*) All electrical apparatus and conductors shall be . . . . efficiently . . safeguarded, and so installed, worked and maintained as to reduce the danger through accidental shock or fire to the minimum, ...

Rule 6.—The insulation of every complete circuit other than telephone or signal-wires used for the supply of energy, including all machinery, apparatus, and devices forming part of or in connection with such circuit, shall be so maintained that the leakage-current shall so far as is reasonably practicable, not exceed $\frac{1}{1000}$ of the maximum supply-current, and suitable means shall be provided for the immediate localization of leakage.

Rule 7.—In every completely insulated circuit, earth or fault detectors shall be kept connected up in every generating and transforming station, to show immediately any defect in the insulation of the system. The readings of these instruments shall be recorded daily in a book kept at the generating or transforming station or switch-house.

Rule 10.— . . . . Gloves, mats, or shoes of indiarubber or other non-conducting material shall be supplied and used where the live parts of switches or machines working at a pressure exceeding the limits of low pressure, have to be handled for the purpose of adjustment.

SECTION II.—GENERATING-STATIONS AND MACHINE-ROOMS.

Rule 5.— . . . . Insulating floors or mats shall be provided for medium-pressure boards where live metal-work is on the front or back.

SECTION VI.—ELECTRIC LOCOMOTIVES.

Rule 3.—In order to prevent any other part of the system being earthed (except when the concentric system with earthed outer conductor is used) the current supplied for use on the trolley-wires with an uninsulated return shall be generated by a separate machine, and shall not be taken from or be in connection with electric lines otherwise completely insulated from earth.

Mr. J. F. LEE wrote that the author had dealt with a subject which, in view of the Special Rules recently adopted, was of widespread interest, and any information that he could give which would lead to a true method of recording the amount of leakage-current on a three-phase installation would be an advantage. At present, there appeared to be no reliable means of knowing whether there was slight leakage on a three-phase system. Before the Special Rules came into use, the means adopted for roughly testing leakage in a three-phase installation under his (Mr. Lee's) charge was to place an incandescent lamp on the switch-board, one connection being made to the conductor and the other to the "earth," so that if there was sufficient current passing it would be indicated by the glow of the lamp. When the plant was at work, the distinct glow of the lamp shewed that there was a slight leakage on the system. All joint-boxes and connections were thoroughly overhauled, and the cable tested in lengths along the whole distance, but no leakage could be found. The next important point was to find the cause for the lamp lighting when put in circuit with earth; and, after investigation by experts, it was considered to be due to the capacity of the system. As an experiment, a second lamp was put in circuit together with the first; and there was no apparent change in the intensity of the light of the first lamp and the second lamp showed the same glow as the first lamp. Since the Special Rules came into force, one of the recently introduced earth-detecting instruments had been fixed in the same position as that taken by the lamp. It was calibrated so as to read from 1 up to 50 milliamperes, and was arranged so that it could be connected by a switch on to each phase or conductor separately, or on to all three of the conductor-cores combined. This instrument, when connected to earth and to each phase separately, gave readings of 33, 33 and 33¾ milliamperes respectively; but, when connected to the three phases on one side or what was termed "normal point," there was no deflection of the needle. Whether the indicator was an incandescent lamp, or an instrument by which the current could be measured, it was quite clear that there was a current from each phase to earth. Assuming that the deflection shown on the instrument was due to capacity or partly to leakage-current and partly to capacity-current, could Mr. S. F. Walker explain how the leakage-current

could be measured, and so enable the Special Rules to be carried out by indicating immediately any defect in the installation of the system, as well as the limit of 0·1 per cent. of the maximum current?

Mr. KENELM EDGCUMBE (London) wrote that, in the case of the sixth Special Rule of Section I., extremely vague ideas appeared to prevail as to what was meant by "leakage-current," and it might be well to point out that the leakage, in this case (which must not exceed 0·1 per cent. of the maximum supply-current) was not that flowing from either main to earth, but that flowing from one main through the earth into the other. Several makers had stated that the indications given by their instruments were the actual leakage-currents, as required by the Special Rules. This was, however, not so, since: (1) The indications depended on the resistance of the instrument; (2) they had no relation to the true leakage-currents, as defined above; and (3) the readings were enormously affected by the state of the insulation of the other main, which was not (at the moment) under test. To obviate this difficulty, Mr. F. C. Raphael had devised a set of instruments for various systems, constructed broadly on the lines mentioned by Mr. S. F. Walker. In the case of the direct-current instrument, which was of the moving-coil pattern, a direct-reading table was supplied, from which not only the insulation of each main separately, but also the leakage-current from main to main, could be read at a glance.

Mr. Walker suggested that a bell or other alarm could be readily added, so as to draw the attention of the attendant to the fact that a leak had occurred. In the case of the direct-current instruments mentioned above, this was done; but with alternating current, owing to the fact that there was always a certain capacity-current flowing to earth, the problem was more difficult, and it was not usually found worth while to add the signalling-device.

In his last paragraph,* Mr. Walker rightly stated that none of these instruments would indicate the fact that a few feet of bare cable were resting on the ground, provided that the latter were dry; the reason being, of course, that there was in this case no leakage, and the instruments were only designed to indicate leakage.

* *Trans. Inst. M. E.*, 1905, vol. xxx., page 414.

The amount of attention now being given by mining engineers to electrical work was most gratifying to electrical engineers, and the problems presented in connection with the satisfactory enclosure and insulation of live parts in a damp mine were extremely interesting.

Mr. W. Moon (London) asked whether, in the measurements made by Mr. G. C. Wood* at Armstrong College, proper contact had been made with the coal, as he had pointed out in his paper† by buttering two opposite sides with clay and pressing tinfoil on them; and whether the coal was in its natural state, as taken from the mine, that is, saturated with moisture, or whether it had been exposed to the air so long as to become quite dry.

For instance, the measurement of the resistance of Permian sandstone of 8,375,000 ohms per cubic centimetre seemed to have been made on dry stone, rather than on the stone as it existed in the quarry. He (Mr. Moon) saturated all the stones that he had measured and then wiped their surfaces before making any measurements of the specific resistances. He appended some measurements (Table I.) of stone that he had obtained from the Bath Stone Firms, Limited; and he regretted that he had destroyed the figures giving the results of his experiments, else he might have given the members some other measurements that would possibly have been of interest.

TABLE I.—SPECIFIC RESISTANCES OF BATH STONES.

Description of Bath Stone.	Specific Resistances per Cubic Centimetre. Ohms.	Description of Bath Stone.	Specific Resistances per Cubic Centimetre. Ohms.
Caen	2,100	Kempstone	10,500
Portland	5,500	Bradford	25,000
Do.	6,400	Ancaster	26,000
Chalk	7,700	Corngrit	28,600
Monkspark	8,100	Corsham	31,500
Doubting	9,000	Farleigh	32,000

With regard to the specific resistance of coal, he (Mr. Moon) suggested that cubes, about 1 decimetre, or 4 inches on the side, should be formed in the coal-mine, as the coal was worked. The pieces should then be immersed in a vessel containing water, carried to the laboratory, wiped dry, and measured as described in his paper.

* *Trans. Inst. M. E.*, 1905, vol. xxx., page 99.

† *The Electrical Review*, London, 1904, vol. liv., page 485.

The writer had made some experiments on the saturation of different stones by water, soaking them for a certain time and cleaving them, and judging from the appearance of the cleaved surface how far the water had penetrated; and he found, with some of the harder stones, that the rate was as low as a centimetre (0·4 inch) a day.

He (Mr. Moon) thought that the possibility of getting earth could only be determined by practical experiments in coal-mines. But, personally, until at least he was in possession of further data, he should say that it would be a mistake to earth any part of an electrical plant in a coal-mine. Two things should be considered in an electrical plant in a coal-mine:—(1) The risk of shock, and (2) the risk of explosion.

With regard to the former, he thought that the normal voltage of the circuit formed only a slight guide as to the danger. One could sometimes handle with impunity a pressure of 500 volts, when the skin was dry and the voltage steady. But even 100 volts were unsafe, if the skin were damp with perspiration and the current was surging in the wires. It was, in fact, not the normal voltage that constituted the danger, but the surgings in the current that might run 100 volts up to 1,000 volts, when, for instance, a faulty motor was being driven. It was well known that men had been killed with the normal pressure of 100 volts.

For ordinary purposes, concentric cables, sheathed and with the sheathing earthed, would seem to be the safest for use. But in a coal-mine, a short-circuit of a concentric cable might cause an explosion, and he suggested that it would be better to keep the two wires of the circuit as far apart as possible, to rely upon their insulation and not to place any earthed conductors, of any sort, near them. He (Mr. Moon) thought that the danger from sparking or short-circuiting was more to be feared in a coal-mine than the danger from shocking; and he anticipated that Mr. S. F. Walker had reached the same conclusion.

It was certainly useless to employ enclosed armatures and fuses, if arcs or sparks could take place between the conductors, or between one of the conductors and an earthed pipe, which could scarcely be kept airtight throughout its length.

Mr. John Gregory said that if the armouring was sufficiently earthed, it was difficult to see how a man standing on the ground

could possibly receive a dangerous shock. If they assumed that the earth was so poor a conductor that the potential in the live armour, which was earthed, was still maintained, the earth must fulfil the same purpose as the indiarubber mats or gloves. In any case, whilst there was a copper-wire, or other equivalent, connecting the live armour to the earth, it was not probable that a man's body (of infinitely higher resistance) could transmit a dangerous amount of current. The use of an uninsulated return was not, by any means, accepted as a wise proceeding. If it were used, and a man standing on the ground touched any portion of the insulated main, whether at a switch-box, fuse-box, or motor, he was bound to receive the full pressure; but if both mains were insulated, and the insulation was well maintained, the chances were that he would receive a very slight shock, dependent on the effectiveness of the insulation. Even assuming that a fault did occur in a cable and that the armour was made alive, if this was efficiently earthed, it fulfilled the conditions of an uninsulated return. Could Mr. Walker give any particulars of an earth-detecting device which would measure the leakage-current as well as the capacity-current, and discriminate between the two?

Mr. W. C. Mountain (Newcastle-upon-Tyne) said that he had always maintained that, as far as possible in mining installations, it was desirable to use an entirely insulated system throughout. The concentric system, consisting of a copper central core and an iron-wire return (the iron wire being used as armouring and earthed), was, in his opinion, a dangerous and an unsatisfactory system to adopt. He knew of several instances where fatal shocks had occurred through the earthing of the outer conductor, and there was also the possibility of electrolytic action being set up. In addition to this, the system was objectionable, on account of the difficulty of repairs; and, generally, the only recommendation that this system had was one of cheapness. From his experience, the bulk of the trouble, with colliery-installations, had arisen through the accidental earthing of the conductors; it put an undesirable strain upon the insulation of the generators, motors, etc., and certainly 99 per cent. of the accidents to armatures and field-coils underground had occurred through a bad earth on the system.

He (Mr. Mountain) believed that he originally suggested the use of the earth-detector to the Departmental Committee on the Use of Electricity in Mines. He was well aware of the many accidents that had occurred through earth-leakage, and he felt that some ready method of showing, at a glance, whether the system had maintained its insulation-resistance or not was necessary. His intention was that the earth-detector should be used as an indicator only, but his original suggestion had been considerably elaborated. These elaborations were not called for by the sixth Special Rule of section I. To comply with this rule, a testing-set, consisting of an instrument, which would accurately read the insulation-resistance of the circuits, was required; and an ohm-meter, that was, an instrument to read ohms: these instruments being also styled, "meggers," "ohmers," etc. They consist of a small electric generator, contained in a case, with a driving handle; and they show the insulation-resistance on a dial of any circuit very simply and quickly.

The earth-detector, required by the seventh Special Rule, section I., is merely an instrument (such as a low-reading ampere-meter), which is graduated, and shows whether the insulation-resistance has fallen or not. In the ordinary way, the finger of the instrument would stand at a certain point; if the insulation-resistance fell, the position of this finger would alter, and it would immediately act as an indication that there was something wrong with the system which required investigation, and then the testing set would be required to ascertain what was the actual resistance.

It seemed to him that periodical insulation-tests over the whole of the system were necessary; and he was sure that, if this were done, it would reduce the number of breakdowns of electrical plant very considerably, and be a great saving to the colliery-owner.

It was not so difficult to get a good earth as one would gather from Mr. Walker's remarks; and in his experience, with mining work, the great difficulty had been to prevent earths. It was desirable to have one good earth, and this could generally be obtained by putting an earth-plate in the sump, or by attaching the earth-wire to the pump-columns and water-pipes.

If amoured cables were used, the armouring should be continuous throughout, and if the armouring was efficiently con-

nected to earth in the way described, the results obtained would be satisfactory. There could be no doubt that it was very necessary, in all systems where armoured cables were used, that the armouring should be properly and thoroughly earthed throughout the whole system.

Mr. JOHN MORRIS said that, in dry mines, the use of the tram-rails, when laid in the ordinary way, for earthing electrical apparatus was absolutely dangerous. Rails, laid on wooden sleepers, often had ¼ inch or more of space at the joints, and it would be a poor earth that would require the current to leap an air-gap of ¼ inch to make it; rails laid on iron-sleepers, with fish-plated joints, were but little better, unless special means were taken to make them electrically continuous; and, for making efficient earth, colliery tram-roads should not be used. Again, there might be, in an otherwise dry colliery, certain places where a little water issuing from the roof might be caught in a little sump, and tanked away. This little sump, on first thoughts, might appear to form a good place for earthing any electrical apparatus that might be near it. It was conceivable, under certain circumstances, that the sump, as a means of making efficient earth, would be nothing better than an earthenware tank; and, due to the resistance of the strata from the little sump to the earthed terminal of the earth-detector on the surface, the detector might show a good insulation while the earth-wire from the little sump to the apparatus supposed to be earthed might be at a dangerous potential: the strata simply acting the part of a choking coil. Consequently, in dry mines, they could not depend on having an efficient earth, unless it were made by an electrically-continuous metallic conductor to some pond, well or running water; and considering the various conditions under which electricity was now used in mines, he (Mr. Morris) doubted whether, under all circumstances, they could depend on having a proper earth unless the current was carried through armoured concentric cables, all apparatus being earthed and the earth-detector being connected to the armouring. Then, on making a good connection to earth from some point of the armouring, they would thus form a proper earth for all apparatus.

Mr. P. C. POPE (Manchester) said that he did not believe that there was an earth-detector, in compliance with the Special

Rules, on a three-phase installation; but he thought that the best practical appliance was to place an electrostatic earth-detector between each main and earth. In addition, a volt-meter, graduated in ohms, should be used for testing, every day, each main, and reading the actual insulation-resistance to earth on each main. Electrostatic earth-detectors should be placed between each main and earth, and from their construction they would never actually put any main to earth. The only instrument that he had seen used for that purpose was practically a volt-meter, graduated in ohms, and put to earth as described by Mr. Walker. It immediately lowered the insulation-resistance of the whole plant; and, although that might be high, from the fact that the instrument was placed between both conductors and earth, the plant might give a shock to any man. The electrostatic earth-detector would always indicate earth-currents, without at the same time putting the whole installation to earth, the weak point of all the instruments now being introduced into mines. No earth-detector had, at present, been designed, however, which was of any use on a three-phase system, where the neutral point was permanently earthed. He (Mr. Pope) did not think that there was any instrument at the present time that would take account of capacity-currents as well as earth-currents.

Mr. John Gregory said that Mr. Pope pointed out the danger of connecting the volt-meter through to earth, and recommended the use of an electrostatic instrument; but he was informed that an electrostatic instrument could not be used on the voltages in common use in collieries. He had received particulars of an electrostatic earth-detector, available for 2,000 volts and upwards, but he was advised that it was not suitable for pressures of 400 or 500 volts.

Mr. P. C. Pope said that one particular make of earth-detector would work at a pressure of 20 volts.

Mr. W. C. Mountain remarked that the seventh Special Rule, section I., did not call for such accuracy as the speakers seemed to suppose.

Mr. John Gregory said that the rule limited the leakage-current to 0·1 per cent.

Mr. G. G. L. PREECE said that uninsulated concentric cables should not be used in mines. He had known cases where the outer conductor was doing just sufficient damage to cause leakage, and he had actually seen arcing between the inner and outer conductors. Where armoured cables were used he thought that the concentric was the safest, but they must be insulated, as there was more exposure and increased liability to damage. The difficulty of earthing in very dry mines depended upon whether armoured cable should or should not be used; but, taking all things into consideration, the single unarmoured cable was most suitable for use in a dry mine, so long as metal hangings or similar appliances were prohibited. He agreed with Mr. Pope that electrostatic earth-detectors could be used with low voltages.

Mr. ROSLYN HOLIDAY said that they might use what they thought was earthing, but H.M. inspector of mines might say "this appliance is not efficiently earthed," and the members had looked to Mr. Walker's paper to tell them, once for all, what was good earth. He knew of a colliery where armoured cables had been removed, because the moisture in the air caused them constantly to take fire. From his own experience, he must say that cables were much better if they were well insulated, but without armouring. With this great difficulty of earthing, if they could insure that the armouring was perfectly earthed throughout the whole system, it would not matter if the armouring became alive—nobody could get a shock. But he had not learned any means of ensuring that the armouring was perfectly earthed; and therefore with armoured cables there was great risk of the armouring coming into contact with the conductor.

Mr. SYDNEY F. WALKER, replying to the discussion, said that he had tried to drive home in his paper the fact that in certain mines it was practically impossible to earth. He (Mr. Walker) had written against the use of concentric uninsulated returns for the last twenty years, or as long as the subject had been under consideration. He did not advise it now, but he did say, if they must have armouring, and it must be earthed in order to comply with the Special Rules, that the concentric system was the best, because it afforded warning of a break in the armour. Reference had been made to both mains being insulated and the

armouring alive and earthed, but, if the armouring was at the same potential as the ground, they would not get a shock. But he maintained that, if a cable was insulated and armoured separately, and the armour was earthed, there would be conditions under which a man would get a shock.

Mr. J. Morris had asked about a device to discriminate between leakage-currents and capacity-currents; but he enquired of the members whether it was really wanted. They knew from hard experience that the capacity-current existed, as the current had to be generated; and they had found out by a process of elimination that it was there, but delicate tests with an apparatus, such as would be required to show its existence and to measure it, would be totally out of place in a mine. He agreed with Mr. Mountain that earth should be kept off the system, and that continuous tests should be made with that object. He agreed with Mr. Morris that, in dry mines, the rails and so on were of no use for earthing; as the current had to travel from the rails to the sleeper, from the sleeper to the ground, then to the next sleeper, and so on, and then to whatever was used as earth: the path being one of very high resistance. He also agreed with Mr. Morris that the little water-sump would be similar to the use of an earthenware tank, and a drop of water in a battery-jar would make as good an earth.

He ventured to prophesy that engineers who used electrical apparatus, especially as current and tension increased, would have trouble unless earth was kept out of the system; and he was glad to find that Mr. Holiday had adopted this view.

Mr. S. Mavor (Glasgow) wrote that Mr. Walker referred to himself as having preached for twenty years in favour of the use of insulated cables without armouring. In the early days of electrical engineering, it was the usual practice, doubtless also followed by Mr. Walker, to mount dynamos and motors on timber bases, so as to insulate their frames from earth. The prejudice in favour of this practice had died hard, but it was dead; and it was now recognized that the best method was not only to refrain from insulating, but definitely to earth the machine-frame. A similar prejudice still survived in the objection to earthing the outer conductor of a concentric cable. Opinions as to the undesirability of earthing the outer conductor of the concentric system were freely given, but there was a singular

paucity of argument. The general statement was reiterated that it was desirable to maintain the complete insulation of the system. It was forgotten that every tramcar-motor worked with one side connected electrically to earth; and it could not be said that their conditions of service were less exacting than those of motors used in mines. If a motor was not sufficiently well insulated to run with one side connected to earth, it was not good enough for mining work.

Many mining engineers did not clearly realize that the fact of a cable carrying current did not render it a live cable, in the sense that shock might be experienced from touching it. One might, therefore, be excused from here laying emphasis on the fact, that the shock experienced depended on the difference of electric pressure between the cable and earth, and not upon the current passing through the cable. If this were understood, it must be obvious that a system of wiring, in which the insulated conductor (the one at a potential different from that of earth) was completely surrounded by an earthed metallic sheathing (stranded wires over the cable, and cast-iron boxes over switches, fuses, etc.), whose continuity was ensured by its use as the return-conductor, could not be a source of danger to the men in the mine. Access to the inner or live conductor could only be gained by opening the covers of the cast-iron boxes containing the switches, fuses, etc., or at the dynamo- or motor-terminals. Now the Coal-mine Regulation Acts prohibit any but "authorized persons" to deal with such appliances; and the authorized persons know and avoid the certain danger of touching the parts within the boxes or the motor-terminals. There was with concentric wiring, with earthed outer wires, a sharp and unmistakable dividing-line between safety and danger for the authorized person, and there was absolute safety for the unauthorized, so far as he was liable to come into contact with cables and switch-boxes. From the latter class, two of the three victims of fatal mishaps during the past twelve months had been drawn.

As Mr. Walker stated in his paper, the only way of ensuring absolute and permanent safety from contact with cables, if armouring were used, was to adopt the concentric system with an uninsulated return. The difficulty in connection with ordinary armoured cables was the permanent maintenance of the electrical continuity of the armouring throughout the whole

mine, or of the earth-connections made at various points. In Mr. Walker's opinion, and in that of the present writer, the maintenance of the condition on which safety depended was impracticable. If armouring was not to be used, where was the insulating material to be found that would be permanent, when subjected to the atmospheric conditions of a mine, and of sufficient mechanical strength to resist abrasion? Such a material had not yet been found, at all events it was not in general use; and it was proved by the fact that a considerable number of fatal accidents had occurred by contact with cables, from which the insulation had rotted or had been abraded.

In a recently published summary* of the fatal accidents due to electric shock, which had occurred in the past twelve months, three of these were associated with mining work, and the causes were stated as follows:—(1) Grasping a bare rapper or signal-wire made live by leakage from temporary wiring; (2) found dead grasping an electric cable; and (3) fuse, nipped between the lid and the case of a cast-iron fuse-box, which was ineffectively earthed. Not one of these accidents, and they were the only fatal mining accidents on the list, could possibly have occurred if concentric wiring, with an uninsulated outer conductor, had been used.

Mr. W. THORNEYCROFT (Glasgow) wrote that an experience of about fifteen years' use of the concentric system of wiring, both for lighting and power, might be of interest to members. It was impossible for anyone to get a shock from the cables wherever they might be, and he believed that it was impossible for anyone not engaged in handling the motors or switches to get a shock at all. For those so engaged, the danger-points were very clearly defined, and the number of such points was only one-half of that of a similar installation on the twin-wire system. The strain on the insulation of the armatures was greater with the concentric, than with the twin-wire system. When an armature developed a slight defect, slight shocks might be got from the motor-casings, when these were bolted down on wooden seats; but before the shock became dangerous the fuse melted and cut off the current. As regarded durability, cables that had been in use for ten years underground had been taken out and put to work in another pit, where they were working to this day. A

* *The Electrical Review*, London, 1905, vol. lvii., page 408.

cable in a wet upcast-shaft had been in use there for twelve years, and it was still working without trouble. A similar cable in the same shaft was taken out after ten years' work, because the power conveyed by it was no longer required. It was more or less corroded, and was not considered good enough to use again; but, if left alone, it would probably have worked for a much longer time.

One of the motors, served by the cable referred to above as still working, was over a mile from the dynamo; and many engineers said that, under these conditions, electrolysis would destroy the armouring in a short time, and that various other troubles would prevent satisfactory work. But the facts did not support their argument. So far as he was aware, there had never been a burst cable, except as the result of an accident, such as hutches, running away down an incline, striking the cable and crushing it. When this occurred, the current at once made a short circuit, and the fuse on the surface gave way. At the point where the accident occurred, there was a bright flash, caused by the arc, for a second or two before the fuse went. This flash would undoubtedly kindle an explosive mixture of gas and air, but it was of too short duration to set on fire any timber in contact with it.

Any intelligent man could learn to make a junction; but badly made junctions were the cause of most cable-failures.

He might add that several collieries under his supervision had adopted the twin-wire system, but he preferred the concentric system because it was, in his opinion, the safest. It was obviously easier to run one cable to a given point than two; it was simpler and easier to manage; and, as regarded the cost of installation, there was not much difference either way.

Where continuous current up to 500 volts was suitable, he was of opinion that for mining work, both above and below, the concentric system of wiring was the best; but, of course, it must be concentric throughout, and should not be mixed with the twin-wire system.

The PRESIDENT (Sir Lees Knowles) proposed a vote of thanks to Mr. Walker for his paper.

Mr. P. C. POPE seconded the resolution, which was carried with acclamation.

DISCUSSION OF MR. T. Y. GREENER'S PAPER ON "THE FIRING OF BABCOCK AND OTHER BOILERS BY WASTE-HEAT FROM COKE-OVENS.*

Mr. T. Y. Greener (Crook) thought that it was desirable, in commenting upon the general discussion, to preface his remarks with the statement that he had not the least intention, as some of the speakers seemed to think, of comparing the respective merits of Babcock-and-Wilcox and Lancashire boilers for general purposes, or of advocating the use of one in preference to the other. So far as the facts and figures, that he (Mr. Greener) had set forth in his paper, constituted in themselves a comparison of the results obtainable from the two classes of boilers, that comparison was restricted to boilers fired by the waste-heat from coke-ovens under widely different conditions; and, therefore, the results, although they might fairly be regarded as an indication of the comparative efficiency of the two sets of boilers for a particular purpose, could not be accepted as conveying more than that. The primary object of a coke-maker was to manufacture good coke, and therefore it was quite certain that he would not imperil that object for the sake of a few points of increased efficiency in any boiler.

With regard to Mr. A. L. Steavenson's remarks, he (Mr. Greener) proposed to give some figures, on the lines asked for by Mr. M. Deacon, as to the capital-expenditure involved in installing different classes of boilers on ovens, and those figures would answer Mr. Steavenson's question. He (Mr. Greener) had no reason to think, from his experience of Lancashire and Babcock-and-Wilcox boilers, that the latter were more costly to uphold than the former. In some cases pit-water was used, and in others surface-water; and he confidently expected that at the end of 20 years both descriptions of boilers would be in good working order.

He (Mr. Greener) did not, of his own knowledge, know the calorific value of the coke-oven gas produced from Pease's West coal, but he believed that the value of gas from which the bye-products had been extracted was about 400 British thermal units.

It might be true, as Mr. Gerald H. J. Hooghwinkel stated, that the chimneys attached to the boilers were too low, although he did not think so; if they were higher, the draught on the

* *Trans. Inst. M. E.*, 1905, vol. xxix., page 362.

ovens would be too great, and there would consequently be waste in burning the coke, and difficulty in regulating the admission of air to the ovens.

The use of spare gas in gas-engines for colliery-purposes would, he (Mr. Greener) had no doubt, be extensively adopted in the future; but, at present, in this country at least, the application of such engines at collieries was only in the experimental stage, and he did not know of more than one colliery at which they had been adopted.

TABLE I.—CAPITAL-OUTLAYS ON BOILERS PER 1,000 GALLONS OF WATER EVAPORATED PER HOUR.

Name of Colliery.	Class of Boiler.	Capital-outlay per 1,000 Gallons of Water Evaporated per Hour.
Ushaw Moor ...	Lancashire, 30 feet long and 7½ feet in diameter	£1,250
Do. ...	Lancashire, 30 feet long and 7½ feet in diameter	1,220
Bankfoot	Lancashire, 30 feet long and 7½ feet in diameter	1,550
Esh	Lancashire, 30 feet long and 8 feet in diameter	1,781
Esh	Lancashire, 30 feet long and 9 feet in diameter*	1,064
Bowden Close ...	Babcock-and-Wilcox, 1,426 square feet of heating-surface	1,758
Bankfoot	Babcock-and-Wilcox, 1,827 square feet of heating-surface	1,427
Stanley	Babcock-and-Wilcox, 2,823 square feet of heating-surface	1,023
Ushaw Moor ...	Babcock-and-Wilcox, 2,823 square feet of heating-surface	862

* Five flues.

The results that Mr. W. C. Blackett had obtained from the Babcock-and-Wilcox boilers at Kimblesworth colliery were remarkably good, and he did not know of anything to equal them elsewhere. It was clear, having regard to the temperature of the flue-gases at the back of the Lancashire boilers at Kimblesworth and Sacriston collieries, that all the heat was not being utilized, and that an additional boiler or an economizer might with advantage be applied in each case.

He (Mr. Greener) did not agree that his calculations should have been based upon an evaporation of 12 pounds of water per pound of coal from a hand-fired Babcock-and-Wilcox boiler. He had not ascertained how much water such boilers would evaporate if hand-fired with Pease's West coal, but he thought

that it would not exceed 8 pounds, possibly 10 to 12 pounds per pound of combustible in the coal used. Still, having regard to the fact that the coal contained a large percentage of dirt, he was of opinion that the figure used in his paper was about correct.

With regard to Mr. M. Deacon's request for information, as to the comparative capital-outlay on each kind of boiler per 1,000 gallons of water evaporated per hour, he (Mr. Greener) had ascertained the costs of each of the boilers on that basis at the several pits referred to in his paper and the results were recorded in Table I. He (Mr. Greener) was afraid that this information was not of much value for comparative purposes, inasmuch as the conditions in each case were widely different, and, hence, the expenditure in installing the boilers varied in proportion to the relative value of such conditions. He thought, however, that given precisely the same conditions, the cost would not be very different for each class of boiler.

He (Mr. Greener) agreed with Prof. L. T. O'Shea that the results obtained at Ushaw Moor colliery, and by Mr. W. C. Blackett at Kimblesworth colliery, could not be realized with gases from which the bye-products had been extracted; and, with a view of testing the results obtainable with such gases, he had recently had tests made of the evaporation from a Lancashire and a five-flue boiler, fired by waste-heat and spare gas from which the bye-products had been extracted, from 25 Otto-Hilgenstock retort-ovens at Saint Helens colliery. The results were set forth in Table II. The temperature of the gases at the back

TABLE II.—EVAPORATION-TEST OF BOILERS AT SAINT HELENS COLLIERY.

Duration of test	24 hours.
Water evaporated per hour	10,372 pounds.
Coal coked per hour	12,320 ,,
Water evaporated per hour per pound of coal coked	0·840 ,,
Water evaporated per hour at and from 212° Fahr.	0·907 ,,
Temperature of feed-water	162° Fahr.
Pressure of steam per square inch	60 pounds
Temperature of gases at front of boiler	2003° Fahr.
Temperature of gases at back of boiler	800° Fahr.

of the boiler was evidence that the whole of the heat was not being utilized; and arrangements had therefore been made for firing a third boiler with the waste-heat from the Otto-Hilgenstock ovens. These ovens only commenced work about two months ago, hence it was possible that they might not yet have

attained their full heat. It was estimated, before the ovens were built, that about 1 pound of water per pound of coal coked would be evaporated by the waste-heat; and ultimately that expectation might be realized. He was, however, somewhat doubtful whether it would.

No tests had been made, such as those suggested by Mr. C. C. Leach, to ascertain to what extent, if any, priming took place from Babcock-and-Wilcox boilers. Having regard, however, to the steam-supply from these boilers at each of the collieries mentioned, it was quite certain that the water lost by priming was very small.

Mr. S. F. Walker's remarks were exceedingly interesting and suggestive, and it had not occurred to him (Mr. Greener) before reading them, that it was possible that the steam obtained by waste-heat at the several collieries referred to, could equal in work done that obtainable from gas-engines. He had, however, looked into the figures, and assuming that 10,000 cubic feet of gas were given off by each ton of coal coked; that the gas had a calorific value of 365 British thermal units, and that one-third of it was available for use in gas-engines; and that such engines would require 30 cubic feet of gas per brake-horsepower: then the horsepower from such gas-engines, combined with the horsepower obtainable from the waste-heat, would be just about equal to that capable of being produced from the steam raised from the waste-heat and spare gas in engines using 16 pounds of steam per brake-horsepower. Such engines were not in everyday use at collieries: as a rule, in his opinion, colliery-engines did not consume less than 40 pounds of steam per brake-horsepower, and on that basis the use of gas-engines would be more economical than the use of steam-engines.

Mr. William Severs (Beamish, County Durham) wrote that he had had tests made with the boilers at the Mary pit, Beamish colliery. There are 120 beehive coke-ovens attached to 4 five-flued boilers, 30 feet long and 8½ feet in diameter, with 1,398·71 square feet of heating surface. The feed-water is put into an old cylindrical boiler, placed upon the flue between the boilers and the chimney; and, afterwards, the feed-water is pumped from this boiler to the five-flued boilers placed at the end of the coke-ovens. The average results of several tests are recorded in Table III.

TABLE III.—RESULTS OF EVAPORATION-TESTS WITH FIVE-FLUED BOILERS HEATED WITH WASTE-GASES, AT BEAMISH COLLIERY, MARY PIT.

	I.	II.	III.	Averages of the three Trials.
Date of trial 1905	Aug. 28	Aug. 30	Sept. 1	...
Duration of tests ... .. hours	6	6	6	...
Temperature of gases at the front of the boilers ... degs. Fahr.	1,750	1,783	1,783	1,772
Temperature of gases at the back of the boilers ... degs. Fahr.	575	616	628	606
Temperature of gases at the chimney ... ... degs. Fahr.	483	531	543	519
Water-gauge at the front of the boilers ... ... inches	0·5	0·5	0·5	0·5
Water-gauge at the back of the boilers ... ... inches	0·8	0·8	0·8	0·8
Water-gauge at the chimney inches	1·1	1·1	1·1	1·1
Temperature of feed-water degs. Fahr.	104	104	104	104
Coal coked per hour pounds	16,240	16,240	16,240	16,240
Water evaporated per hour ,,	20,330	23,963	25,373	23,222
Water evaporated per pound of coal coked ... pounds	1·250	1·470	1·560	1·426
Water evaporated per square foot of heating-surface of boiler pounds	3·633	4·283	4·535	4·150

Dr. F. SCHNIEWIND (New York) wrote that there were but few isolated instances of waste-heat boilers, applied on beehive coke-ovens, and, regarding the results of their operations, practically no data were at hand. The comparison between the economy of the waste-heat recovery of beehive coke-ovens, and the conditions of operation prevailing in the bye-product oven were so far apart, however, and so well understood, that they hardly need be touched upon in this connection.

DISCUSSION OF MR. M. R. KIRBY'S PAPER ON "THE COMPOUND WINDING-ENGINE AT LUMPSEY MINE."*

MR. M. R. KIRBY, replying to the discussion, wrote that of late years some very fine and costly engines had been built for winding, some being compound and fitted with valve-gears leaving nothing to be desired with regard to steam-distribution.

* *Trans. Inst. M. E.*, 1905, vol. xxix., page 380.

The performances of these engines, however, so far as he had been able to gather, had been disappointing, the lowest steam-consumptions attained being 55 to 60 pounds per actual horse-power per hour. He, therefore, considered that he was justified in stating that the results obtained at Lumpsey mine were satisfactory. However, Mr. John McLaren might be able to inform the members of lower steam-consumptions. The valve-gear at Lumpsey mine was admittedly bad, the good results being due to the low-pressure throttle-valve which was, he believed,* unique at the time when it was adopted. He would also like to state here that he was not responsible for the valve-gear. The steam-consumptions, tabulated in his paper, included all the steam used for winding, by the feed-water, air and circulating pumps, and for raising and lowering men; and it was described in his paper as being used for "other purposes."

He (Mr. Kirby) believed that he thoroughly explained in his paper the disappointing results of the condensing tests; and as a large number of tests were carefully made, and agreed pretty closely, he did not consider that there was any error in his figures. He agreed that tests on other winding-plants would be interesting and useful; and it would be desirable that they should be carried out by a committee of the members of the Institution, so as to ensure uniformity.

He (Mr. Kirby) regretted that he was not in a position to give the data asked for by Mr. S. L. Thacker. The only way of stating the commercial efficiency of a winding-engine was to ascertain the amount of fuel used to raise a given weight to a given height, and this result was most easily and accurately stated (as indicated in his paper) as "coal used per actual horse-power-hour."† It would be seen, on referring to the results of the test of March 25th, 1904, of the Lumpsey winding-engine, that while the steam-consumption was highest the evaporation was best, owing to the high temperature of the feed-water.

He (Mr. Kirby) agreed with Mr. B. Woodworth that better results would have been obtained with a cut-off at 80 to 85 per cent. of the stroke: this, indeed, was part of his original scheme, but unfortunately it was not adopted. The several winding-engines were never reversed, and seldom braked to any extent: and the mechanical efficiencies given in his paper were undoubtedly obtained.

* *Trans. Inst. M.E.*, 1905, vol. xxix., page 382.

Mr. M. Deacon doubted whether so low a steam-consumption as 35 pounds per actual horsepower per hour could be obtained with a non-condensing cross-compound winding-engine. He (Mr. Kirby) hoped shortly to erect such an engine, and he would communicate the results of tests upon it to the members.

He (Mr. Kirby) agreed with Mr. T. C. Futers that, in many cases, it was easy to try to save too much steam at too great an expense.

Engineers usually aimed at commercial efficiency, and if stone could be wound for a less weight of coal with a compound than with a simple winding-engine, that was quite enough reason for its adoption.

The power delivered at the engine throttle-valve, at Lumpsey mine, cost (including fuel, interest on capital, depreciation, upkeep and labour) about 0·55d. per actual horsepower per hour.

He (Mr. Kirby) did not agree with Mr. P. Kirkup that the use of triple-expansion winding-engines should be limited to deep mines, and he pointed to the use of the cross-compound winding-engine at Lumpsey mine, where only 9¼ revolutions were made per wind, in support of this contention.

The poor results obtained by condensing arose from the fact that the condensing plant, which was working on the winding-engine alone, was designed to condense the steam from all the engines at the mine; and, now that it was performing its full duty, it was much more efficient.

It was quite as easy, when drawing stone, to work the Lumpsey winding-engine condensing as non-condensing; for light loads, such as drawing men and shaft-work, the engine was rather quick, and the exhaust-steam was turned into the atmosphere when such work was being done.

Mr. R. H. Fowler (Leeds) wrote that he noted, from the diagrams which Mr. Kirby had taken from the high-pressure cylinder, that although automatic gear was fitted, it did not come into operation. This, he thought, was not to be wondered at, seeing that the engine only made between nine and ten revolutions to complete the wind, and, therefore, there was not sufficient time for the automatic gear to act. He noticed in the remarks that Mr. John McLaren had written on Mr. Kirby's paper that he compared marine and other engines working under the most favourable conditions, and requiring from 11 to 13 pounds of

steam per indicated horsepower, with the Lumpsey winding-engine, which required from 38 to 42 pounds per indicated horsepower per hour, and was surprised that such a consumption should be tolerated. It appeared to have escaped Mr. McLaren's notice that a winding-engine worked under the most unfavourable conditions, and that it had to put in motion an immense mass of material as quickly as possible, and bring it to rest again, frequently under one minute of time (in the case of Lumpsey in about 27 seconds). He (Mr. Fowler) thought that such a comparison as Mr. McLaren had made was not at all applicable. Taking into consideration all the circumstances with which Mr. Kirby had to deal, he (Mr. Fowler) considered that he decided on the alteration, to the engines as he found them, that would give the most economical results at the lowest outlay; and the saving of fuel, that had resulted, fully justified the change that he had made.

Mr. B. Woodworth (Longton, Staffordshire) wrote that he still thought that the shaft-load efficiency of the Lumpsey mine winding-engine recorded in Mr. M. R. Kirby's paper could not be correct, as it was as high as would, probably, be guaranteed for a high-class continuous-working pumping-engine; and in his (Mr. Woodworth's) opinion a mechanical efficiency of 60 per cent. was rarely obtained from a winding-engine under normal conditions.

He (Mr. Woodworth) felt convinced that the tests were not carefully made, and it was almost certain that a stroke or a revolution, used under steam to finish the wind, had not been taken into account at all. If so, that would reduce the shaft-load efficiency from 10 to 20 per cent.; and there would be retardation of the high-pressure cylinder, owing to steam being stored in the receiver, between the high-pressure and the low-pressure cylinders. The winding-engine at the Ferreira mine showed a shaft-efficiency of 67·8 per cent.; and the shaft-efficiency of the winding-engine at the Village Deep mine was said to exceed 85 per cent.*

Mr. G. H. Winstanley read the following paper on "Mining Education in the Victoria University of Manchester":—

* *The Engineer*, 1906, vol. ci., page 365.

MINING EDUCATION IN THE VICTORIA UNIVERSITY OF MANCHESTER.

BY GEORGE H. WINSTANLEY.

Introduction.—Throughout Great Britain, during the last quarter of a century, there has been a widespread development of what has been called "industrial education," being the practical application of the arts and sciences to the industries. Everywhere in the United Kingdom, institutions have been founded to meet the demand for higher education, and naturally, in most instances, the character of the instruction provided is largely influenced by the industries of the locality.

Mining Education.—Mining generally, and coal-mining in particular (the most important of British industries, not merely because it is helpful, but absolutely essential to all the others), curiously enough has been among the last to receive the attention which its importance deserves, and to have placed at its disposal similar educational facilities to those enjoyed by other industries. It is true that something has been done, here and there, in the past; and recent years have seen the establishment of several important centres of mining instruction. In Lancashire, an institution (in which it has been the writer's privilege to have charge of the Mining Department for twelve years, and until a year ago) has done good work in mining education for nearly half a century. During the period that he had charge of this department, the average number of students attending the mining classes alone was about 140 annually. The record of those twelve years includes 300 successes in the higher stages of the Board of Education (Science and Art Department) mining examinations, including 52 passes in the honours stage; whilst in the examinations for colliery-manager's certificates, in the two Lancashire centres, more than 180 students were successful in gaining certificates of competency. These figures, constituting a record which, so far as the writer knows, is without parallel,

are given in order to show that, although the Mining Department in the Manchester University is new, and the writer's duties there have scarcely begun, he personally can at least lay claim to some little experience in mining education, as a result of which he feels justified in advising the scheme of instruction which, after conferring with various mining authorities, the Manchester University has decided to adopt.

One by one, the Universities, situated on the coal-fields or near centres of mining industry, have embraced mining education within their field of operations, and in Lancashire it was felt that there was room for something beyond the provision already made. Indeed, a demand had arisen for more advanced education in mining for which (as the seat of learning in one of the greatest industrial cities of the Empire, and the commercial centre of one of the most important British coal-fields) the Victoria University of Manchester felt called upon to provide.

In the establishment of a system of mining education, a difficulty encountered at the outset is that no two authorities seem to be quite agreed as to the best course to adopt. As a matter of fact, from an educational standpoint, mining is quite unlike any other industry, and it is not possible to formulate a scheme of instruction suitable for the training of a mining student on lines which might prove highly successful, say, for a student in engineering. In the management and working of a modern colliery, one requires to possess an intelligent knowledge of nearly all those sciences which are capable of practical application, including mathematics, chemistry, metallurgy, physics, mechanics, geology and electricity. Not only is a knowledge of these matters essential, but one must be able to apply that knowledge usefully in connection with the numerous and varied operations coming within the scope of the colliery-manager or of the mining engineer. At the same time, one must not lose sight of the fact that mining is an industry and not a playground for experimental science; that collieries are not carried on to give scope for the practice of ideas of questionable utility evolved from brains endowed more liberally with ingenuity than with common-sense; but that they are, or should be, profit-earning concerns, which, whilst finding employment and providing a means of livelihood for 800,000 of the dwellers in Great Britain, produce a reasonable return

for the capital expended upon their development and equipment. Any system of mining education, which loses sight of this fact, entirely fails in its object and becomes worse than useless. The student must be brought to recognize that the chief object of his studies is the practical attainment of efficiency, economy, and safety in mine-management and working.

The writer's experience has led him to the conclusion that an elaborate and costly equipment is quite unnecessary for mining education. The existing physical, chemical, metallurgical and engineering laboratories provide all that is requisite in the way of laboratory-practice for the mining student in his academical career.

For practical work in mining, the best possible laboratory is the mine, and in no other laboratory can the student so satisfactorily acquire practical knowledge of mines and mining. It is quite impossible to provide adequately in the College or University for his practical training: any attempt to do so by the expenditure of large sums of money on model mines and galleries, intended to represent mine-workings, can only give the student an entirely erroneous impression of the real thing; and when, in later life, he passes from the artificial and unreal (where everything can be "made to order," and coming events anticipated and provided for on scientific lines) to the stern realities and responsibilities of mine-working and management, he is quite unfitted for the work before him. Often, too, the student so trained comes upon the scene (perhaps unconsciously) with a distorted sense of his own abilities, even amounting to a feeling of superiority over those possessing the experience of a life-time, and this will have a most unfortunate influence upon his further progress and development. His practical training will suffer also from a disinclination to ask for information, either from a feeling that such a course would appear, in his case, undignified; or more probably because his untrained eye fails to note details which may be of the greatest importance. He has become familiar with phenomena artificially reproduced, with which it is perhaps not well to become too familiar, in the sense that one kind of familiarity begets indifference if not something worse. On the other hand, he is confronted from time to time with conditions which cannot be reproduced in a model mine, and with which he has no previous acquaintance.

He is taken unawares by occurrences for which his college-training has not made provision, and which do not appear in the programme for the day.

Practical Training.—If he is to become a successful engineer, the mining student must, at the earliest possible stage in his career, become acquainted with the real thing. He must grow up, so to speak, in the atmosphere and environment of the mine; and while he gains experience and widens his knowledge of practical mining, he should simultaneously engage in the study of those sciences which bear upon the operations with which he is daily becoming more conversant.

From the very commencement of his practical training, however, the student should feel that he has some responsibility. This is a feature of the most vital importance; no matter how simple his early duties may be, he should feel that he is personally responsible for something; and, in this way, he develops greater interest in his work, and derives greater benefit from his practical experience. On the other hand, occasional visits to mines and collieries, and summer holidays spent in a sort of conducted tour, which seem to form a feature in some schemes of mining education, must, in the great majority of cases, prove futile. The student becomes a mere privileged visitor who may "look-but-not-touch," and whilst he may regard with interest, at the time, everything that he sees, little or no impression of a lasting character is made upon his mind, because he has not felt the burden of responsibility, or played any part which he could feel was of real use in connection with the work in hand.

Victoria University of Manchester Scheme of Concurrent Practical Training.—In the scheme which has been adopted in the Victoria University of Manchester, these points have been carefully considered, and it has been recognized that there is no useful substitute possible for the training which the student can only acquire in the mine; and that, in the interests of the mining industry, no attempt should be made to find a substitute. Adequate provision is made for laboratory-practice in connection with physics, chemistry, metallurgy and engineering; but the mine is accepted as the best laboratory for practical work in mining. The Victoria University scheme, therefore, provides

that the student shall have facilities for acquiring practical experience during his academical career, so that he may usefully combine and blend the scientific with the practical. Of course, the University cannot undertake actually to provide the practical training; but, in order to render such a system of concurrent training practically possible, the interest and assistance of a number of colliery-companies has been secured, and these companies, whose collieries are situated within easy reach of Manchester, are prepared to receive, as articled pupils or apprentices to mining engineering, approved students recommended by the University.

Degree Course.—The course leading to the degree extends over three years; and during the second and third years the student spends certain days each week in the University, and occupies himself at the colliery on the remaining days. The intention is that when the student has completed his preliminary or scientific year in the University, he should enter at once upon practical work, spending two days a week at the colliery. During the third year, he is enabled to spend more time at the colliery, the classes and lectures requiring his attendance at the University only on three days of the week. This arrangement, of course, applies to students who desire to concentrate their attention upon coal-mining. The absence of metalliferous mines in the immediate neighbourhood of Manchester makes it impossible to adopt exactly the same course for the student of metalliferous mining; a similar arrangement has, however, been made with the owners of certain metalliferous mines, where the student will spend three months in each year in practical work.

Diploma Course.—To meet the requirements of the Coal-mines Regulation Act for students preparing for the mine-manager's certificate of competency, a two years' certificate course has been arranged.

Mining Lectures.—The mining lectures, of a thoroughly practical character, embrace operations in coal and metalliferous mines, and deal exhaustively with the mechanical engineering and equipment of collieries and mines. As far as possible,

operations and appliances, capable of illustration, will be placed before the student with the aid of the optical lantern in a fully lighted room, a plan which affords the greatest possible assistance to the student. Lantern-slide diagrams are especially useful in connection with the details of complicated mechanical appliances, which it would be scarcely possible to place before the student in any other way, and by which the action and construction of various appliances can be clearly explained to the student.

Conclusion.—The thirteen years of experience in mining education, during which the writer has been brought into contact with about one thousand mining students drawn from all classes, have convinced him that the concurrent system of mining training, as embodied in the scheme adopted by the Victoria University of Manchester, is the best. His experience has been that the most successful students were invariably those whose practical training and scientific or technical education had proceeded simultaneously.

The PRESIDENT (Sir Lees Knowles, Bart.) moved a vote of thanks to Mr. Winstanley for his paper.

Mr. M. WALTON BROWN seconded the resolution, which was cordially approved.

Mr. J. T. STOBBS read the following paper on "The Value of Fossil Mollusca in Coal-measure Stratigraphy":—

THE VALUE OF FOSSIL MOLLUSCA IN COAL-MEASURE STRATIGRAPHY.

BY JOHN T. STOBBS.

1. INTRODUCTION.

It is wellknown that coal-seams are subject to great changes in their commercial qualities; thickness; amount, distribution and nature of their impurities; character of roof and floor; and these changes render their identification over wide areas a matter of great difficulty, and when referred solely to these physical qualities, the result is merely a guess. A most excellent example of the labour and uncertainty of the correlation of coal-seams without palæontology, is given in *An Account of the Strata of Northumberland and Durham as proved by Borings and Sinkings*, published by the North of England Institute of Mining and Mechanical Engineers.* It is desirable, therefore, to call in the support of fossil-evidence, so far as it may be available, to enable us to fix the relative position of the seams, not only in different parts of the same coal-field, but also in different coal-fields. It is one of the objects of this paper to show the extent to which this evidence is in our possession, and has already been used for this purpose.

One of the most disappointing features of the science of geology is its comparative neglect of the Coal-measures. At the present time, our knowledge of the Ordovician, the Silurian, and the Cretaceous systems is much more detailed and exact than that of the 3,000 feet, more or less, of Coal-measures, although the latter are of more importance to civilization than all the other geological formations combined. In proof of this uncertainty and confusion, the following remarks recently made by Mr. Aubrey Strahan, of H.M. Geological Survey, may be cited, and the reference is of greater interest to us

* "No. 452.—Levels of Chirton Colliery, as taken by Mr. John Barnes, 1755," vol. ii., C-E, pages 50-51.

to-day, meeting, as we do, practically on the ground in dispute. "The difficulty lay in correlating the measures proved at Bradford with those at Astley, and in determining the relative positions of the Bradford Four-feet seam and the Worsley Four-feet seam. There were more than 3,000 feet of strata in question."* Of what other rock-system would such a statement be true to-day? Obviously, this condition of science is just the reverse of what ought to exist, and it is not easy perhaps to make out how it has arisen. No doubt, the extraordinary persistence of coal-seams in comparison with their associated strata, and the ease with which they can be traced, have contributed most to the neglect of palæontology, as a working-aid in Coal-measure exploration.

2. Coal-measure Mollusca in our Museums.

In some measure, the neglect of the mollusca is due to our public museums. Being desirous of seeing lamellibranchs from various coal-fields the writer, this year, made a round of the museums situated at the following important centres, namely:—Manchester, Newcastle-upon-Tyne, Leeds and Nottingham; in every instance the only impression that could be received would be, that locally, plants and fishes were of the utmost importance, and that the mollusca were of little consequence. Manchester, with its magnificent collection of Coal-measure plants, had scarcely a dozen specimens of lamellibranchs, from measures above the Arley mine of Lancashire, properly labelled as to locality and horizon. Newcastle-upon-Tyne, with its classical Hutton collection of plants and its Atthey collection of fishes and reptilia, is in a similar plight with reference to molluscs from the Northern coal-field, above the horizon of the Brockwell seam. Leeds and Nottingham are, if possible, in a worse condition, with respect to the shells from the coal-fields of Yorkshire and Nottinghamshire. The Geological Survey Museum at Jermyn Street, London, is not materially different: it contains, possibly, a hundred specimens of Coal-measure mollusca from all the British coal-fields. With very few exceptions, however, the horizons and localities are not sufficiently indicated to be of any stratigraphical value.

* *The Quarterly Journal of the Geological Society of London*, 1905, vol. lxi, page 322.

It is too evident, also, that the great teaching establishments in coal-mining centres have failed to impress upon their students the utility of the mollusca as zonal indices.

3. Coal-measure Mollusca: the two Faunas.

All fossils are not equally serviceable to the practical geologist. For instance, a very rare form, however valuable to biological science, is useless in stratigraphy. This reflection was induced by a perusal of the following list of typical and representative Coal-measure fossils given by Dr. Henry Woodward and Mr. H. B. Woodward in their *Table of British Strata*,* namely:—"*Scorpion*, *Belinurus*, *Etoblattina*, *Euphoberia*, *Cyclus*, *Lepidodendron*, *Sigillaria*, *Calamites*, *Anthracomya*, *Megalichthys*, *Acanthodes*, *Rhizodus*, *Ctenodus*, *Loxomma*, *Keraterpeton*, *Anthrakerpeton* and *Anthracosaurus*," which illustrates the danger of lists where the common and rare forms are not distinguished. To be of use to the mining engineer or field-geologist, the fossils must be fairly abundant and sufficiently well-preserved to ensure determination of species; their range, vertically limited, and horizontally extensive. In that portion of the Coal-measures which is characterized by the occurrence of numerous coal-seams of workable thickness, the mollusca answer these requirements most admirably. To particularize, this sequence comprizes, in Northumberland and Durham, all above the Victoria and Brockwell seams; in Lancashire, from the Arley mine to the Ardwick *Spirorbis*-limestone series; in the Yorkshire and Nottinghamshire coal-field, all above the Silkstone or Blackshale seam; in North Staffordshire, from the Bullhurst seam to the Half-yards ironstone; in South Staffordshire, from the Deep mine to the base of the Red Coal-measure clays; in Glamorgan, from the Engine coal-seam to the base of the Pennant Grit. These measures well deserved a descriptive name, and Sir Andrew Ramsay termed the succession "the true Coal-measures." This sequence has now been subdivided and correlated by means of marine horizons, freshwater-lamellibranch zones and entomostracan limestones; plant- and fish-remains have also been used by Mr. Robert Kidston and Dr. Ramsay Heatley Traquair respectively, but notice of their work does not lie within the scope of this paper.

In the Coal-measures, there are two molluscan faunas, which are never intermixed—a marine type and a freshwater type.

* London, 1901.

During the last few years, considerable attention has been given to the study of these faunas, the most important features of which are that they are easily distinguishable and they are not commingled. Unfortunately, general statements to the contrary are on record. Recently, Mr. A. Strahan said "Though differing from the open-sea deposits which preceded them, the Coal-measures were almost certainly not fresh-water. The *Anthracomya* is known to have lived side by side with true marine molluscs, and the *Carbonicola*, though allied to a great fresh-water family, is always found in close attendance upon the *Anthracomya*."* Particulars of horizon and locality should have accompanied this statement. If *Anthracomyæ* were found side by side with marine fossils on a colliery spoil-heap that would be sufficient validation. The writings of such workers as Messrs. E. W. Binney, J. W. Kirkby, William Molyneux and George Wild, are opposed to this teaching, and recent experience in collecting from marine horizons is equally emphatic.

I.—*Marine Horizons.*

Strata containing marine fossils occur at frequent intervals throughout the true Coal-measures. They often constitute the roof-measures of a coal-seam, and usually contain a large number of fossils; and although the mollusca predominate, they are occasionally accompanied by echinoderms and fishes. The marine bed is generally a black, dark-grey, or grey laminated shale, indistinguishable in its lithological character from other Coal-measure shales. Calcareous bullions, however, occasionally form a noteworthy feature in these shales, as in the roof of the Upper Mountain mine of Lancashire, the Pennystone of South Staffordshire and Coalbrookdale, the shales below the Twist coal, and the roof of one of the Rider coals of the Seven-feet Banbury of North Staffordshire. These bullions should be carefully split along a plane parallel to their bedding, when they will generally reveal fossils in a beautiful state of preservation: they are especially worthy of the attention of collectors. The marine deposits are never very thick—varying

* *Memoirs of the Geological Survey of England and Wales: The Geology of the South Wales Coal-field. Part II.—The Country around Abergavenny, being an Account of the Region comprised in Sheet 232 of the Map*, by Mr. Aubrey Strahan and Mr. Walcot Gibson; *with notes* by Mr. J. R. Dakyns and Prof. W. W. Watts, 1900, page 84.

from 12 feet down to about 3 inches. When very thin, they may easily escape notice, unless specially looked for. The writer is of opinion that these horizons offer the best means of correlating the coal-fields of this country, marking definite, dead-level planes of deposit, over large areas. It is earnestly to be hoped that special search will be made for them in all future sinkings and borings in those coal-fields where few, if any, have as yet been recognized. The writer holds the conviction that they will be found, if looked for.

The mollusca are represented by brachiopoda, cephalopoda, gasteropoda and lamellibranchiata, and the most important forms are: —

(*a*) *Brachiopoda:*—(1) *Lingula mytiloides.* This is nearly always present in large numbers, and sometimes is confined to the topmost layer of the band, unmixed with other species, and thus proving the last survivor of the transient marine conditions.

(2) *Orbiculoidea nitida.* Although this is not so common as *Lingula mytiloides*, the two forms are generally associated together.

(3) *Productus scabriculus.* Very abundant in the Chance Pennystone of Coalbrookdale.

(4) *Chonetes laguessiana.*

(*b*) *Cephalopoda:*—(1) *Goniatites.* Retaining, for the moment, this old-fashioned generic name for certain cephalopods which are very abundant in marine bands, and are, of themselves, sufficient to indicate the marine character of the deposit, we occasionally find them so badly-preserved that whilst no specific determination is possible there can be no doubt that they are goniatites. *Dimorphoceras Gilbertsoni* is one of the commonest forms. *Gastrioceras Listeri* is characteristic of the lowest portion of the Coal-measures.

(2) *Orthoceras.* Individuals referable to this genus are frequently met with, although their specific determination is generally impossible.

(3) *Nautiloids.* These are of rarer occurrence.

(*c*) *Gasteropoda:*—Specimens referable to this class are also comparatively rare, and they are therefore not so useful in stratigraphy.

(*d*) *Lamellibranchiata*:—(1) *Pterinopecten papyraceus*. This shell is one of the most abundant in the marine horizons of the Coal-measures. By reason of its size and shape it readily attracts attention. It is generally associated with goniatites, and together they form, perhaps, the most useful indices of the marine character of the stratum.

While the following forms are not so abundant, they have a wide distribution:—

(2) *Ctenodonta lævirostris*.
(3) *Myalina compressa*.
(4) *Nucula gibbosa*.
(5) *Posidoniella lævis*.
(6) *Pseudamusium fibrillosum*.
(7) *Pterinopecten carbonarius*.
(8) *Solenomya primæva*.

II.—*Marine Bands of Coal-fields*.

It will be understood that any of the species enumerated may be found at any of the marine horizons, for aught that is known to the contrary—and in this respect they differ from the lamellibranch-zones described later. There is a marked difference in the richness of the fauna, not only at different horizons, but from locality to locality in the same horizon.

The writer has drawn up a list, shewing all the marine bands at present recognized in each coal-field, arranged in descending order, that is, the newest at the top.

Northumberland and Durham Coal-field:—(*a*) Ryhope colliery: discovered during sinking at 951 feet from the surface or 592 feet from the base of the Permians at that locality.* This point is 17 feet 4 inches above the Five-Quarter coal-seam.

(*b*) East Rainton: met with in boring, 888 feet below the Hutton seam.†

Lancashire Coal-field:—(*a*) Bradford colliery: Mr. John Gerrard, H.M. inspector of mines, recently discovered a grey

* "On the Occurrence of Marine Fossils in the Coal-measures of Fife," by Mr. J. W. Kirkby, *The Quarterly Journal of the Geological Society of London*, 1888, vol. xliv., page 752.

† "Rock-cores from a Diamond-boring at East Rainton," by Prof. G. A. Lebour, *Proceedings of the University of Durham Philosophical Society*, 1897, vol. i., page 69.

shale from a depth of 2,076 feet, containing *Lingula mytiloides.* It was a very diminutive form, freely distributed through the shale, and not confined to one layer: the writer is indebted to Mr. Gerrard for courteously shewing him the débris from the sinking.

(*b*) Ashton-under-Lyne: exposed in the banks of the river Tame, about 450 feet above the Great mine.* C.

(*c*) Victoria colliery, Standish: Mr. John Gerrard also discovered this bed, about the horizon of the Arley mine.† B.

(*d*) Dulesgate, Colne, Rochdale, Staleybridge, etc.: roof of Bullion coal or Upper Mountain mine. A.

Yorkshire, Derbyshire and Nottinghamshire Coal-field:—(*a*) Gedling colliery: found by Mr. Walcot Gibson during sinking, 524 feet above the Top Hard seam.‡

(*b*) Gedling colliery: found by Mr. Gibson during sinking, 258 feet above the Top Hard seam.‡

(*c*) Midland Railway: cutting, between Pilsley Junction and Clay Cross; the horizon has not been determined.§

(*d*) Middleton colliery, Yorkshire: 82 feet above the Silkstone coal-seam.‖ B.

(*e*) Vicinities of Leeds, Bradford, Halifax, Penistone and Sheffield: roof of the Hard bed or *Pecten*-seam. A.

North Staffordshire Coal-fields: Potteries:—(*a*) Chell and Foley collieries: roof of the Bay or Lady coal-seam.

(*b*) Priorsfield, Longton: roof of the Priorsfield ironstone.

(*c*) Nettlebank and Speedwell collieries: below the Twist or Gin mine. C.

* Marine shells, discovered by Mr. A. H. Green, *Memoirs of the Geological Survey of Great Britain and of the Museum of Practical Geology: The Geology of the Country around Oldham, including Manchester and its Suburbs (Sheet 88 S. W., and the Corresponding Six-inch Maps 88, 89, 96, 97, 104, 105, 111, 112; Lancashire, 259, 271)*, by Mr. Edward Hull; *with an Appendix on the Fossils*, by Mr. J. W. Salter, 1864, page 64.

† "Presidential Address," by Mr. John Gerrard, H.M. Inspector of Mines, *Trans. Inst. M.E.*, 1904, vol. xxviii., page 363.

‡ *Memoirs of the Geological Survey: Summary of Progress of the Geological Survey of the United Kingdom and Museum of Practical Geology for 1902*, 1903, page 14.

§ *Ibid.*, pages 15 and 16.

‖ "On the Fossil Animal Exuviæ of the Yorkshire Coal-field," by Mr. Henry Denny, *Proceedings of the Geological and Polytechnic Society of the West Riding of Yorkshire*, 1845, vol. ii., page 293.

(*d*) Florence colliery and Slippery Lane: a short distance below the (*c*) horizon.

(*e*) Longton Hall colliery: about 110 feet above the Moss coal-seam.

(*f*) Silverdale No. 16 pit, Sneyd, Berry Hill and Florence collieries: roof of the Moss Cannel or Single Two-feet coal-seam.

(*g*) Leycett, Minnie pit, Halmerend, Hayes Wood, Talk-o'-th'-Hill, Birchenwood (No. 18), Sneyd and Norton collieries: above the Seven-feet Banbury coal-seam. B.

(*h*) Weston Sprink: horizon unknown.

(*i*) Knypersley Reservoir: below the Winpenny coal-seam.

(*j*) Wetley Moor: roof of the Crabtree coal-seam. A.

Cheadle:—(*a*) Draycott colliery: 71 feet below the Four-feet coal-seam.

(*b*) Churnet Valley: roof of the Crabtree coal-seam, three marine bands. A.

Leicester Coal-field:—(*a*) Leather Mill: horizon not exactly known.*

(*b*) Church Gresley: roof of the Ryder coal-seam.*

(*c*) Nailstone colliery: 453 feet below the Lower Main coal-seam.†

(*d*) Nailstone colliery: 507 feet below the Lower Main coal-seam.†

(*e*) Nailstone colliery: 521 feet below the Lower Main coal-seam.†

(*f*) Nailstone colliery: 663 feet below the Lower Main coal-seam.†

South Staffordshire Coal-field:—(*a*) Hamstead colliery: 195 feet above the Thick coal-seam.

(*b*) Between Rowley Regis and High Haden: White ironstone.‡

(*c*) Oldbury: Pennystone ironstone.‡ C.

(*d*) Cannock Chase: below the Cannel coal-seam.§

* *Burton-on-Trent: its History*, by Mr. William Molyneux, 1871, page 154.

† Cores in Leicester Museum.

‡ *Memoirs of the Geological Survey of Great Britain, and of the Museum of Practical Geology: Geology of the South Staffordshire Coal-field, etc.*, by Mr. J. Beete Jukes, second edition, 1859, page 58.

§ *Burton-on-Trent: its History*, by Mr. William Molyneux, 1871, page 154.

Coalbrookdale Coal-field:—(*a*) Freehold, Donnington: Chance Pennystone.

(*b*) Donnington: above the Blackstone.*

(*c*) Lodgewood pit: Pennystone. C.

Bristol Coal-field:—(*a*) Ashton Vale colliery: over a new coal-seam, 270 feet below Gay's vein coal-seam.†

South Wales Coal-field:—(*a*) Beaufort: mine over Bydyllog coal-seam.‡

(*b*) Clydach, Pontypool and Sirhowy: mine over the Engine coal-seam.§

(*c*) Glan Rhymney, Beaufort, Cwm-Bryn-ddu: Rosser veins.||

The large letters, A, B and C, at the end of some of the lines, indicate the same marine horizon in each coal-field.

III.—*Freshwater Horizons.*

Freshwater lamellibranchs.—Lamellibranchs are by far the commonest shells in the Coal-measures, and since the death of Mr. J. W. Salter, in 1869, they were comparatively neglected in this country, till Dr. Wheelton Hind, in the last decade, took up their study. It is much to be deplored that the Geological Survey, during those years, allowed Mr. Salter's work to be dropped, for it had a direct economic bearing. Dr. Wheelton Hind first reduced the disorganized facts to order, by drawing up a scheme for "zoning" the Coal-measures by means of the three wellknown genera of freshwater lamellibranchs, namely:—*Carbonicola, Anthracomya* and *Naiadites*.¶ Whilst the stratigraphy has required some correction, our extended knowledge of the distribution of these genera has added proof of the sagacity and acumen with which the main palæontological lines were laid down

* "On the Geology of Coalbrook Dale," by Mr. Joseph Prestwich, Jun., *Transactions of the Geological Society of London*, 1834-1836, second series, vol. v., page 445.

† Discovered by Mr. H. Bolton, 1905.

‡ "On the Fossils of the South Welsh Coal-field," by Mr. J. W. Salter, *Memoirs of the Geological Survey of Great Britain and of the Museum of Practical Geology: The Iron-ores of Great Britain*, 1861, page 229.

§ *Ibid.*, page 228. || *Ibid.*, page 221.

¶ "A Monograph on Carbonicola, Anthracomya and Naiadites," by Dr. Wheelton Hind, *Palæontographical Society*, 1895, vol. xlix., pages 154 to 170.

by Dr. Hind. Some few of the species are of diagnostic value, that is, they are restricted to one horizon. In other instances an "aggregate" of species is necessary as an index of position. In working-out this faunal sequence, the North Staffordshire coal-field forms the type for reference—chiefly because its wonderful palæontological material has been more diligently collected and carefully studied than that of other coal-fields, and in this work the names of Mr. John Ward and Dr. Hind must be mentioned. The result, then, of the influence and teaching of these pioneers, of much discussion with them, and of collection in many of the coal-fields, is that the following seem to be the most important "zones" in the natural order of succession, from the top of the series (of Coal-measures) downwards.

(*a*) *Anthracomya calcifera.* This form is found generally in North Staffordshire, near the base of the Newcastle-under-Lyme series: it is also sparingly found between the two lowest coal-seams in that series, but is abundant in the basal limestones—its vertical range here is about 60 feet. At the same horizon in Glyn Morlas, a tributary of the Ceriog, in the Denbigh coal-field, the same fossil is found;* and at Slade Lane, near Manchester.

(*b*) *Anthracomya Phillipsi.* This is one of the best zonal molluscan forms: it is usually very abundant, and it has been traced over an immense area. Its position in the various coal-fields is given below:—

South Wales: Mr. Walcot Gibson found it in the roof of No. 1 Rhondda seam, near Blaen-gwrath.

Bristol and Forest of Dean: Dr. Wheelton Hind obtained it from one of the seams at Kingswood pit, Bristol, and Trafalgar pit, Cinderford.

North Staffordshire: It is very abundant in the laminæ of the blackband ironstones, the Top Red mine, the Half-yards or Blackband, the Red mine, the Red Shag and the Bassey mine: it is also common in the Gubbinstone at Silverdale, at Forge pit, Chesterton, and in Hanley. Its range here is about 700 feet vertical.

* *Memoirs of the Geological Survey: Summary of Progress of the Geological Survey of the United Kingdom and Museum of Practical Geology for 1900*, 1901, page 101.

Lancashire: It is abundant in the Upper Coal-measures containing the *Spirorbis*-limestones, at Ardwick, Slade Lane and Bradford colliery.

Yorkshire and Nottinghamshire: Mr. Walcot Gibson found it at Gedling sinking, 524 feet above the Top Hard coal-seam.* It was also discovered, this year, in the railway cutting near Cadeby (Conisborough) in a 3 inches ironstone, 10 feet below the Permian at that locality.†

It is important to recall the fact that Mr. Robert Kidston, in 1893, recognized these red beds as "most probably, if not certainly, Upper Coal-measures."‡ The discovery of *A. Phillipsi* enables us to speak with certainty on the question.

Northumberland and Durham: Last month, the writer was fortunate enough to discover this fossil in the northern bank of the river Wear, opposite Claxheugh, near Hylton. It occurred abundantly in certain nodules of ironstone, and in this position would be about 1,700 feet above the Hutton Seam. These are known to be the highest beds in the coal-field, and it is important to be able to fix their position with respect to the measures in other coal-fields. Until this discovery, no definite idea could be formed of what sequence of measures had been removed by denudation previous to the deposition of the Permian. We now know that the topmost measures in Durham correspond to the top of the "true Coal-measures" in the Midlands, and in South Wales. The pre-Permian denudation has been a boon to the mining-industry in the north, because the measures immediately above the *A. Phillipsi* horizon in other coal-fields are barren of workable seams.

(*c*) *Carbonicola Vinti.* This small fossil—the last survivor of the genus—is found in North Staffordshire in marls and thin ironstone-bands about 30 feet above the Bassey mine, that is, towards the lower portion of the *Anthracomya-Phillipsi* zone. It likewise occurs in the Hylton section, opposite Claxheugh, in the Durham

* *Memoirs of the Geological Survey: Summary of Progress of the Geological Survey of the United Kingdom and Museum of Practical Geology for 1902*, 1903, page 14.

† "Preliminary Note on Upper Coal-measures in Yorkshire," by Messrs. H. Culpin and G. Grace, *Proceedings of the Yorkshire Geological and Polytechnic Society*, 1905, vol. xv., page 330.

‡ "On the Various Divisions of British Carboniferous Rocks, as determined by their Fossil Flora," by Mr. Robert Kidston, *Proceedings of the Royal Physical Society*, Edinburgh, 1893, vol. xii., page 210.

coal-field, described above, and there also it is associated with *Anthracomya Phillipsi*. It is very abundant in both localities. No better index of the position of a bed in the series of Coal-measures is known than the combination of these two forms.

(*d*) *Anthracomya pulchra*. This curious little lamellibranch is found abundantly in the Burnwood ironstone of the Newchapel area of North Staffordshire, and in South Wales in the mine over the Big coal-seam of Rhymney.

(*e*) *Anthracomya Adamsi*. The very size of this shell is such that it cannot escape observation, and it forms an excellent zone-fossil. In North Staffordshire, it is restricted to the horizon of the New-mine ironstone (of the Newchapel area) or the Little mine (of the Fenton area), which by its aid, are known to be one and the same bed. In South Wales, it has been found in the mine over the Big coal-seam at Rhymney, and in the Black Pins and Soap veins of Ebbw Vale. The writer has seen specimens from the Derbyshire and Nottinghamshire coal-field, but the horizon was unknown.

The close association of these two species of *Anthracomya* in districts so far apart as South Wales and North Staffordshire forms a good zonal index.

(*f*) *Carbonicola turgida, Carbonicola subrotunda and Carbonicola gibbosa*. This horizon is fixed by this "suite" of species of *Carbonicola*. In North Staffordshire, it lies about 100 feet above the Moss coal-seam, and has been traced from Burslem to Longton. In Lancashire, *Carbonicola turgida* and *Carbonicola subrotunda* are formed together above the Cannel coal-seam at Hulton colliery. The writer has seen the full "suite" from an unknown horizon in the Nottinghamshire coal-field.

A little caution is necessary in dealing with *C. turgida*, if found singly, as its zone is rather a thick one, extending in North Staffordshire from the Ironstone coal-seam to the horizon given above.

(*g*) *Carbonicola subconstricta* (special variety) *and Carbonicola turgida* (small variety). In the North Staffordshire coal-field, these special varieties are abundant and associated together in

the roof of the Five-feet coal-seam, which is largely worked on the west side of the coal-field. In this district, they form together a reliable index-band, and it will be interesting to learn whether it holds in other coal-fields.

(*h*) *Naiadites carinata, N. modiolaris, N. quadrata, Anthracomya modiolaris and A. Williamsoni.* In North Staffordshire, this "aggregate-" zone is restricted to the roof of the Hard mine (the Bowling Alley coal-seam of Biddulph). It has been traced throughout the coal-field. In South Wales, the Ras Las coal or Nine-feet coal-seam is at the same horizon—the full "suite" having been found there in the neighbourhood of Rhymney and Dowlais. The writer has also seen all the forms from one horizon in the Nottinghamshire coal-field, but no account could be obtained of its position with respect to a known coal-seam.

(*i*) *Carbonicola acuta*, var. *rhomboidalis.* In North Staffordshire, this variety is restricted to the roof of the Cockshead seam. Associated with it and also restricted to this horizon is a peculiar form of *C. acuta*, where the posterior end is curiously beaked. This may only be an abnormal development of this part of the shell of *C. rhomboidalis*, which in some individuals shows a tendency in this direction.

(*j*) *Carbonicola robusta.* "Mussel-bands," almost entirely made up of this shell, have been found in many coal-fields.

Durham: roof of the Brockwell seam, Horsley Wood, Wylam.

Lancashire: 12 feet below the Arley mine, Chisnall Hall colliery; 54 feet below the Three-Quarter seam, Tyldesley colliery; and roof of the Arley mine, Burnley coal-field.

Nottinghamshire: ironstone-band above the Black Shale coal-seam, Mapperley colliery.*

North Staffordshire: roof of the Cockshead coal-seam; cannel-coal below the Cockshead coal-seam.

South Staffordshire: 30 feet below the Deep coal-seam, Cannock and Rugeley, Wood pit.

South Wales: about the horizon of the Cnapiog coal-seam, Hirwaun.

* *Memoirs of the Geological Survey: Summary of Progress of the Geological Survey of the United Kingdom and Museum of Practical Geology for 1902*, 1903, page 13.

Caution is also necessary with this shell: its maximum development is at the horizons named, but individuals are found, generally associated with *Carbonicola acuta*, from the Ten-feet coal-seam to the Wetley Four-feet coal-seam of North Staffordshire; and from the Arley measures to the Lower Mountain mine of Lancashire. It certainly characterizes the lowest portion of the "true Coal-measures."

Two of the commonest forms of lamellibranchs, namely:—*Carbonicola acuta* and *Carbonicola aquilina*, are of no use for zonal purposes. The former ranges from the top of the Millstone Grit, right through the Coal-measures, to the horizon of the Radstock series of the Somerset coal-field, where Mr. James McMurtrie found the single specimen now preserved in the South Kensington Natural History Museum. The latter is generally associated with *Carbonicola acuta*, though it has not so great a vertical range.

These freshwater mollusca are generally found in black or dark-grey shales of the Coal-measures. They are frequently in such numbers, and so compressed and cemented together, as to form hard beds termed "mussel-bands:" in this condition the shells are often difficult to determine. Occasionally, however, they occur more sparingly and lie scattered through the shale; in these circumstances they are better preserved and are more desirable as specimens. Sometimes, only casts of their interiors are preserved, and these require much care in naming. Generally, the valves are found with their longer axes parallel to the bedding-plane of the shale: a few instances have been observed of the shell being erect in the shale, as if they had been overwhelmed whilst in the act of burrowing in the mud. In the same band, entomostraca are often found side by side with the lamellibranchs and, not infrequently, the shells have *Spirorbis* attached to them. In collecting, note should be made of these circumstances.

It is probable that they were of freshwater habitat, because of the relationship of *Carbonicola* to the recent *Unio*; some of the *Carbonicolæ* have their umbones eroded, the pitting in many instances being very deep and following the lines of growth of the shell. This erosion is characteristic of freshwater-shells. The complete separation of the two faunas observed *in situ* lends

strong support to the view, that as one of them is incontestably marine, the other is freshwater.

The development of the genera is also of great interest. Near the base of the "true Coal-measures," when conditions were favourable, we find the large forms, and all three genera strongly represented. *Anthracomya* attains its maximum at the *Adamsi*-zone, dwindling gradually upwards to the *Phillipsi*-zone, and becoming extinct with the diminutive "*calcifera*." Similarly, one of the latest forms of *Carbonicola* is the little species termed *vinti*.

Some of the above zones may possess a local importance merely, but others again have been shown to have a wide distribution. As our knowledge of their distribution grows, some species not mentioned in this paper may prove to be of greater utility, but in all cases experience will teach us within what vertical and horizontal limits they are most helpful. At this stage it would be unwise to claim too much for these zones; so much depends on the stratigrapher. As a matter of fact, however, in North Staffordshire they have been tested and applied in boring, sinking, and proving faults with great economic advantage, and scientific principles that pass the ordeal of commercial application, can no longer be regarded as belonging to the domain of hypothesis.

4. The Mollusca Compared with Plants and Fishes as Zonal Indices.

The writer holds no brief for the mollusca on this question: on the contrary, he rejoices in receiving help from every source. All these organic remains, when scientifically collected and authoritatively examined, should tell the same story as to the age and relative position of the rocks in which they are found. In the Coal-measures, above the *Anthracomya-calcifera* zone, the plants practically have the field to themselves, with the exception of a few entomostracan limestones, which form excellent index-beds. From the top of the *Phillipsi*-zone to the Millstone Grit, the marine bands and the zonal lamellibranchs afford the means of more minute and unequivocal subdivision than the other organic remains. For supplementary work in tracing a single horizon, entomostracan- or *Spirorbis*-limestones, or fish-remains, when these are so abundant in a stratum that it merits the name of

a "fish-bed," are most excellent. Compared with plants, however, the shells are more abundant in definite beds, their tests were of better material for preservation, and during the period of deposition of the Coal-measures they seem to have undergone more rapid mutation.

5. Conclusion.

For the purpose of the development of this work, local helpers are needed in every coal-field. Every addition to our knowledge of the Coal-measures implies a commercial gain to the coal-mining industry.

The writer especially appeals for help in those coal-fields where little collecting-work has been done hitherto.

Mr. John Morris objected to the statement that *Anthracomya Phillipsi* occurred at "the top of the 'true Coal-measures' . . . in South Wales." The No. 1 Rhondda seam, in which that mollusc had been found, was not at the top of the Coal-measures; there were several hundred feet of strata above the Rhondda seam, and, in that distance, there were at least five workable seams of coal.

Mr. John Gerrard (H.M. Inspector of Mines) said that at Bradford colliery, Lancashire, *Anthracomya Phillipsi* occurred with three workable seams above it; and yet it was perfectly correct to say that it was found in the Upper Coal-measures.

He did not quite agree with Mr. Stobbs in regard to the little aid which geology had rendered to mining or to the mining engineer. Geology had not done as much as it ought to have done, and as much as they hoped it would do in the future; but there were many cases on record, in the Lancashire coal-field, where the knowledge of the fossils found in the seams had proved of great value. At Rishton colliery, Mr. William Pickup, who was in charge of the exploration seeking the Lower Mountain mine, noticed clearly defined shell-beds; and by the aid of these shells, contrary to the expressed views of the workers and those who were said to have known the locality, he directed operations and found the coal-seam. Within the last three or four years, at another colliery, the seam was lost in consequence of meeting a fault, which had an unexpected throw, and the presence of a band, containing goniatites, found

above a seam, led to the proving of their position and the right direction of search. Over and over again, the discovery of *Carbonicola robusta* had led to the successful termination of search for the Arley mine.

He agreed with Mr. Stobbs that the attention of mining students should be directed to the value of practical geology, it gave them an interest in their work and it would ultimately develop into knowledge of considerable value.

It were more fitting that mining engineers should look up this question: the famous Atthey collection of fishes in the Newcastle-upon-Tyne Museum was made by a grocer; the splendid collection of fossils presented to Owens' College Museum by Lord Shuttleworth was obtained by a butcher; to-day a weaver in Colne was collecting most interesting fossils from the east Lancashire coal-seams; and Dr. Wheelton Hind, although a busily employed surgeon, found time to thoroughly work out the mollusca of the Coal-measures all over the country.

Mr. G. E. J. McMurtrie said that the Somersetshire coal-field was much faulted, and it was frequently necessary to search for the seams, with very little to guide them except the nature of the ground; but, so far as he knew, in none of the Somersetshire series had any shells been found. An attempt had been made to trace the horizons of the different seams by plant-remains: they had, perhaps, the richest flora in Britain, but it had been, hitherto, of no practical help. He hoped that Mr. Stobbs would succeed in finding in Somersetshire fossil shells of the species described, and thereby confer a great boon on all interested.

Mr. Joseph Dickinson said that the Lower Series of the Lancashire Coal-measures contained a remarkable goniatite, which was associated with the Upper Foot coal-seam above the Gannister seam. He asked whether the same fossil had been found in the Lower Coal-measures of Durham or Northumberland, because it would help to correlate that particular seam with the Lower Series of Lancashire. He believed that the whole of the Coal-measures of Durham and Northumberland constituted the Lower Series of Lancashire.

Mr. Sydney Bates (Mickley) wrote that Mr. Stobbs was to be congratulated upon commencing the study, in a practical way,

of the palæontology of the Coal-measures throughout Great Britain. Hundreds of sections of strata had been tabulated; but, with the exception of a few put down with the diamond-drill, they afforded a very meagre idea of the strata, without considering the flora and fauna of the measures passed through. However, Mr. Stobbs had introduced in a practical form, for the guidance of those who wished to collect from their mines, fossils which would assist in the correlation of the coal-seams.

Mr. Stobbs stated that most of the fossils were of general occurrence throughout the Coal-measures. He (Mr. Bates) had collected fossils from the various coal-seams in the Wylam district; and he had found, with one or two exceptions, that the fauna and flora had horizons practically of their own. Commencing from the Brockwell and lowest seam, there was a bed of shale, varying in thickness from 6 to 15 inches, containing a great number of *Anthracosia*, distributed throughout the shale; and other fossils were of rare occurrence in the strata immediately overlying the seam. The Yard seam, about 60 feet above the Brockwell seam, was immediately overlain by a very coarse clay mixed with nodules of ironstone; then came 7 inches of shale, with layers of *Anthracosia*, but, as stated previously, no other fossils had been found. At the Six-Quarter seam, a little higher up, a distinct change took place: the fauna was absent, *Anthracosia* not having been found in the strata immediately underneath or above this seam; but, in the plant-impressions, *Sphenopteris* and *Pecopteris* were very common, with a number of *Calamites*. The Five-Quarter seam, 27 feet above the Six-Quarter seam, occurred with the above-mentioned flora, with the addition of *Asterophyllites*, which had not yet been found near the Six-Quarter seam. There was nothing of further interest, until the Towneley seam was reached, and there the fauna became very prominent; *Anthracosia* or *Lingula* had not been found, but *Rhizodus* and *Ctenacanthus* had been discovered in the shale adjoining the coal.

Mr. WALCOT GIBSON (H.M. Geological Survey) fully agreed with Mr. Stobbs as to the value of palæontology in determining horizons among the Coal-measures; and he heartily welcomed the enthusiasm that the author was throwing into the investigation of the marine bands. He (Mr. Gibson) would never forget the experience that he had gained in the North Stafford-

shire coal-field; and, year by year, additional marine beds were being found in the Derby-Nottingham coal-field, largely as the result of the knowledge gained in North Staffordshire. The marine beds, east of the Pennine chain, were likely to prove of practical importance; but the time had not yet come to draw a comparison with North Staffordshire, except, perhaps, between the marine horizon associated with the Crabtree and Alton coal-seams. Great caution was needed in the correlation of individual seams over wide areas; the imperfection of the geological record, and the really small amount of material yet examined, must be kept in mind. The rapidity with which the Coal-measures were deposited was also an important factor, as it did not allow of those faunal changes, which in a large measure accounted for the greater reliance to be placed on the zones of many of the other formations. It was even open to doubt how far palæontologists would agree even as to the existence of any true zones in the Coal-measures. The term true Coal-measures was an unfortunate one, as every geological formation was a true one. In the Midland districts, the old-fashioned terms of Upper, Middle and Lower, if not strictly of palæontological value, satisfied the stratigraphist and the practical man.

It was gratifying to find that the author acknowledged the claims for each and all of the fossils, whether plants or animals. In the Upper Coal-measures, plants constituted almost the sole evidence; and instances could be quoted where they formed the only data as to the age of the Middle and Lower Coal-measures.

In Mr. Stobbs' correlation of the marine horizons, it appeared to be premature to assert that those associated with the Arley mine and the Seven-feet Banbury coal-seam were the same. What was the name of the fossil that distinguished it from the A or C horizons? Very little was yet known of that above the Arley mine. Was enough known about the C horizon? The A horizon was well established many years ago by Messrs. E. W. Binney, A. H. Green and E. Hull, and was being found over wide areas in Derbyshire by Mr. C. B. Wedd. It was pardonable to make North Staffordshire a type, but it must not be made too much of a type.

At the present time, it was hardly true that geologists were neglecting the Coal-measures. The science of geology, the author must bear in mind, offered a wide field in which the reapers were unfortunately few. If, however, a census of working geologists were taken, it would be found that a goodly

number (amateur and professional alike) were engaged in the study of the Coal-measures.

Dr. WHEELTON HIND (Stoke-upon-Trent) wrote that he noted with great pleasure and satisfaction that the subject of the identification of definite horizons in the Coal-measures by the various species of mollusca, was being brought prominently before The Institution of Mining Engineers by so strong an advocate as Mr. Stobbs. It was pleasing to find that the horizons of the North Staffordshire coal-field, which he (Dr. Hind) had mapped out some ten years ago, by the various species of *Carbonicola*, *Anthracomya* and *Naiadites*, had proved of value and of economic importance to the mining engineer, and that these horizons held true for other coal-fields. He noticed that the officers of the Geological Survey had recognized that the same broad palæontological lines as those which he had established in North Staffordshire also obtained in the Nottinghamshire and Derbyshire coal-field.* It was stated that three important fossils had not been found in that area; but in the meantime two of them had been found.† *Anthracomya Adamsii* was found at Tibshelf on the waste-heap by Mr. Thomas Norcliffe, and the same fossil was recognized by Mr. J. T. Stobbs in a collection from Gedling, in which he also identified *Anthracomya Williamsoni* from the latter locality. There could be no doubt that, in the past, fossils had been almost entirely neglected by mining engineers and by the Geological Survey; and this was a matter of surprise to him (Dr. Hind), seeing that the mining engineer had received a first-class technical education, and had been taught to observe. He was convinced that if the Geological Survey had employed their palæontologists in the field, instead of confining their energies almost entirely to museum-work, the value of fossil evidence would have been established long ago, and fewer stratigraphical mistakes would have been recorded by the Geological Survey. He hoped that Mr. Stobbs' paper would open the eyes of the mining engineer to the importance of the study of the fossil mollusca of the Coal-measures.

The PRESIDENT (Sir Lees Knowles, Bart.) thought that Mr. Stobbs had found a key to the correlation of the coal-seams. With

* *Memoirs of the Geological Survey: Summary of Progress of the Geological Survey of the United Kingdom and Museum of Practical Geology for 1904*, 1905, pages 5 and 12.

† *Ibid.*, page 12.

regard to the observation that geology had done nothing for mining, two cases occurred to him in which it might have been, or it had been, of considerable help:- -(1) In Caernarvonshire, a mine was pointed out to him, where a sinking had been made below the Carboniferous series; a geologist would have known that the sinking was being made below the Coal-measures. And (2) in Kent, the advice of a geologist led to the discovery of the Coal-measures; and to the possibility of making a channel-tunnel.

Mr. J. T. Stobbs said that *Anthracomya Phillipsi* was found above the No. 1 Rhondda coal-seam, near the base of the Pennant Grit and near the top of the true Coal-measures. It was found throughout the Midland coal-fields in that position, and also in Durham. Unfortunately, in the Radstock series, worked in Somersetshire, overlying the Pennant Grit, these mollusca did not exist, and the only possible help must come from plants. He (Mr. Stobbs) had no doubt that, as research went on, mollusca, both freshwater and marine, would be found in every coal-field; and a knowledge of their distribution would become a necessary part of the equipment of every mining engineer.

In reply to Mr. J. Dickinson, if fossils are of any use as an indication of horizons in the Coal-measures, then, it is known that the Coal-measures in Durham from the uppermost beds to the Brockwell seam, are the equivalents of the Coal-measures in Lancashire, from near the base of the Ardwick beds to the Arley mine, respectively.

Mr. Gibson's remarks might be punctuated with comment and interrogation, but it appeared that, whilst he attached importance to marine bands as guides in stratigraphy, he was yet sceptical as to the value of the freshwater molluscs. The fact must be emphasized, however, that the scheme tabulated in this paper was not challenged either as to sequence or distribution over the coal-fields from Northumberland to South Wales; and amidst all the side-issues raised by Mr. Gibson, that fact must not be lost sight of, as it was of primary importance.

He (Mr. Stobbs) regretted that Mr. Gibson had reverted to the use of the Upper, Middle and Lower divisions of the Coal-measures, as it was a mistake to think that they "satisfied the stratigraphist and the practical man." So long as the lines of demarcation between these divisions had not the same significance in all the coal-fields, they were a delusion and a snare.

There was a touch of irony in Mr. Gibson's re-adoption of these terms, as in the *Memoirs of the Geological Survey of England and Wales: The Geology of the North Staffordshire Coal-fields*, prepared under the direction of Mr. Gibson and published this year, it was evidently found impracticable to use them. For practical mining work and for stratigraphy, as proved in numerous instances, these divisions were too thick to be of real help and value.

Whatever assistance, in future, might be rendered by the geologist to the mining engineer, it could be asserted that, up to the last decade, nearly all the difficult problems of the coal-fields had been unravelled by the mining engineer, and the work that he had accomplished, without any of the powerful aids of palæontology, was remarkable for its accuracy. Help, however, would not be long withheld, for the Carboniferous system was now rapidly yielding to those zonal methods, which were the warp and woof of modern stratigraphy; and it would be strange, indeed, if the Coal-measures alone, of all sedimentary rocks, were to constitute an exception to the general application of those methods.

The PRESIDENT (Sir Lees Knowles, Bart.) moved a vote of thanks to Mr. Stobbs for his interesting paper.

Mr. JOHN GERRARD seconded the resolution, which was cordially adopted.

Mr. W. N. ATKINSON (H.M. Inspector of Mines) proposed a vote of thanks to the Lord Mayor and Corporation of Manchester for the use of the meeting-room; to the President and Council of the Manchester Geological and Mining Society for making the arrangements for this successful meeting; and to the owners of collieries, works, etc., to be visited by the members.

Prof. HENRY LOUIS seconded the resolution, which was cordially approved.

Mr. H. C. PEAKE (Past-President) moved a vote of thanks to the President for his services in the chair.

Mr. J. S. MARTIN (H.M. Inspector of Mines) seconded the resolution, which was cordially approved.

The following notes record some of the features of interest seen by visitors to collieries, works, etc., which were by kind permission of the owners, open for inspection during the course of the meetings on September 13th, 14th, 15th and 16th, 1905:—

ATHERTON COLLIERIES, CHANTERS PITS.

No. 1 Pit.

The No. 1 and downcast pit is 14 feet in diameter. Coal is wound at this pit from the Seven-feet, the Five-feet or Trencherbone and the Yard mines. The shaft is sunk to the Arley mine, which is reached at a depth of 1,824 feet, and passes through the Seven-feet mine at 591 feet, the Five-feet mine at 1,119 feet and the Yard mine at 1,455 feet. The seams dip to the south at a gradient of about 1 in 5. To save time in winding and to avoid hooking-on at an intermediate point in the shaft, the coal from the Seven-feet mine is brought down to the Five-feet mouthing by means of a steep tunnel, rising towards the dip.

One cage winds coal from the Five-feet mouthing at a depth of 1,119 feet, and the other from the Yard mouthing at a depth of 1,455 feet. To accomplish this object, the flat drums of the winding-engine are made of unequal diameter. The drum for the Five-feet mine cage is 10 feet in diameter, while the drum for the Yard mine cage is 13 feet 1 inch in diameter. To counterbalance this, the cage on the small drum weighs 28 cwts. more than the other cage. The double-decked cages hold two tubs of 8 cwts. capacity in each deck. The shaft is fitted with wooden conducting rods as, owing to the room taken up by pump-rods in the shaft, space would not permit of wire-rope guides being used.

The pumping-engine, working at the pit-top, has a cylinder 24 inches in diameter by 48 inches stroke. It has two lifts, one 11 inches in diameter from the Seven-feet mine to the Six-feet mine, and the other lift, 15 inches in diameter, from the Six-feet mine to the surface.

The winding-engine was erected in 1904, at the back of the old engine. The cylinders, 22 inches in diameter by 54 inches stroke, are fitted with Corliss valves, the point of cut-off being controlled by a governor. The differential drums are fitted with post-brakes, and there is a safety overwinding gear.

The lattice-steel headgear was erected in 1904 to replace an old wooden one.

The pit-top is fitted with the Beien kep-arrangement, by which the keps or catches can be withdrawn from under the cage while the weight of the cage rests on them.

There is a small electric plant, used for lighting purposes only, supplying about 600 lamps at the top and bottom of the pit.

The washery, on the Coppée principle, is capable of dealing with 600 tons per day.

There are six boilers, 30 feet long and 8 feet in diameter, worked at a pressure of 100 pounds per square inch.

No. 2 Pit.

The No. 2 and upcast pit is 16 feet in diameter. Coal is wound at this pit from the Arley mine at a depth of 1,800 feet.

The double-decked cages hold two tubs of 9 cwts. capacity in each deck. The shaft is fitted with wire-rope guides.

The winding-engine has cylinders 28 inches in diameter by 60 inches stroke, fitted with Cornish valves and expansion-gear. The conical drum ranges from 16 to 20 feet in diameter.

The fan, of Waddle type, is 45 feet in diameter. It is at present running at 50 revolutions per minute and exhausting about 200,000 cubic feet of air per minute with a water-gauge of 3¼ inches. The fan-engine has a cylinder 28 inches in diameter by 48 inches stroke, fitted with Corliss valves and a condenser.

The air-compressor, of the Riedler two-stage type, is capable of compressing 3,350 cubic feet of free air per minute to a pressure of 70 pounds per square inch. The compound steam-cylinders are 21 inches and 36 inches in diameter respectively, and the compound air-cylinders, 20 inches and 33 inches in diameter respectively, by 48 inches stroke, fitted with Corliss valves, an intercooler for the air and a Wheeler surface-condenser. They are also fitted with a Whitmore combined air-and-speed governor, by which the speed of the engine varies exactly with the quantity of air required. There are two small Ingersoll-Sergeant compressors, held as a stand-by, capable of compressing about 1,000 cubic feet of free air per minute to a pressure of 60 pounds per square inch. The compressed air is used for pumping, hauling and coal-cutting.

There are six Lancashire boilers, 30 feet long by 8 feet in diameter, worked at a pressure of 100 pounds per square inch. A Green economizer, with 360 pipes, is used for heating the feed-water.

DOUGLAS BANK COLLIERIES.

Shafts.—There are two shafts, each 1,971 feet deep. The downcast or south pit is 16 feet in diameter for a depth of about 1,500 feet, and 11 feet in diameter below that depth. The upcast or north pit is 16 feet in diameter throughout. Coal is wound from both shafts. In the south pit, one cage goes to the Pemberton mouthing, a depth of 543 feet; and the other cage goes to the Wigan mouthing, a depth of 1,125 feet. In the north pit, the cages run to the Yard and Orrell mouthings, the depths being 1,797 feet and 1,971 feet respectively.

The cages have each three decks, with two tubs in each deck, each tub holding $7\frac{1}{4}$ cwts. of coal. The three decks are changed separately at the surface, but at the pit-bottoms, the top and bottom decks are changed simultaneously at separate levels, and the middle deck is changed from the same level as the top deck. Self-acting drop-cages supply the lower decks. There are three wire-rope conductors to each cage, each $1\frac{1}{4}$ inches in diameter. Ormerod safety detaching-hooks are fitted to each cage, and, in addition, extra safety-catches are erected in the headgear. Catches or keps are used at the surface and belowground, and are worked by the banksmen and hookers-on respectively.

Boilers.—There are 10 boilers, 5 at each pit, and they are connected by steam-pipes. At the north pit, there are 5 Lancashire boilers, each 30 feet long and 8 feet in diameter, working at a pressure of 100 lbs. per square inch. At the south pit, there are 3 Lancashire boilers, each 30 feet long and 8 feet in diameter, working at a steam-pressure of 100 pounds per square inch; and 2 Lancashire boilers, 30 feet long and 7 feet in diameter, working at a pressure of 65 pounds per square inch. All the boilers are hand-fired, and the boilers, 8 feet in diameter, are fitted with the Hawksley forced-draught arrangement. The boilers are fed by water from the condensers of the fan-engine, forced into the boilers by a Bailey-Davidson force-pump at each pit.

Winding-engines.—The winding-engine at the south pit has two horizontal cylinders, each 28 inches in diameter and 5 feet stroke, fitted with Eatock balanced-wedge slide-valves. The drum for the Pemberton cage is 7 feet 7 inches in diameter at the small side and 9 feet 1 inch in diameter at the large side. The drum for the Wigan cage is 16 feet 4 inches in diameter at the small side and 17 feet 8 inches in diameter at the large side.

At the north pit, the winding-engine has two horizontal cylinders, 30 inches in diameter and 5 feet stroke, fitted with Cornish valves and Daglish cut-off and throw-out gear. The drum for the Yard cage varies from 15 feet 11 inches to 17 feet 11 inches in diameter, and the drum for the Orrell cage from 17 feet 7 inches to 20 feet 2 inches in diameter.

Both of the winding-engines are fitted with steam- and foot-brakes. The brakes are of the strap type, with the exception of the south pit foot-brake, where a Burn brake is in use.

Ventilation.—The mine is ventilated by a Walker indestructible fan, 24 feet in diameter and 8 feet wide, with a double inlet and an anti-vibration shutter. The rope-pulley fly-wheel is 18 feet in diameter, and the driven-rope pulley is 8 feet in diameter, each being grooved for twelve cotton ropes, 1¾ inches in diameter. The fan produces 280,000 cubic feet of air per minute, at an average engine speed of 44 revolutions per minute and a water-gauge of 3½ inches. The fan is, however, not run at its maximum capacity. The fan is driven by a compound condensing horizontal engine. The high-pressure cylinder is 21 inches in diameter and the low-pressure cylinder 38 inches in diameter, with a stroke of 4 feet. The valves are fitted with Meyer expansion-gear. The condenser, of the jet type, is worked from the cross-head of the low-pressure cylinder.

The condensing water is circulated by a Gwynne engine of the enclosed type, with two single-acting cylinders, 9 inches in diameter by 7 inches stroke, making 210 revolutions per minute. The engine works, by means of a belt-drive, a Gwynne centrifugal pump, which lifts the water to the top of a cooling-tower, 50 feet high, erected over the colliery-reservoir. The reservoir contains 2,250,000 gallons of water. There is a hot well and a cold well in connection with the condensers, made from egg-ended boilers, each 35 feet long and 5½ feet in diameter. A float in

the hot well, attached to an indicator in the fan-house, records the level of the water in the well.

Haulage.—The endless-rope haulage on the overhead system is driven by three-phase electric motors: four of 50 brake-horsepower and four of 25 brake-horsepower. The motors are of the Brown-Boveri slip-ring type, working at a pressure of 500 to 550 volts. Each motor starts against the load, by means of a main switch and a liquid starter. The 50 horsepower motors run at 600 revolutions per minute, and the 25 horsepower motors at 800 revolutions per minute. The rope-speed in all cases is at the rate of 2 miles per hour. The reduction in speed is obtained by means of gearing, the rope-pulleys being on the fourth motion shaft.

Pumps.—There are two electrically-driven pumps below-ground of 5 brake-horsepower, each lifting 50 gallons of water per minute against a head of 130 feet. The Brown-Boveri motors for these pumps, of the squirrel-cage type, work at a speed of 1,200 revolutions per minute and a pressure of 500 volts. The pumps are of the three-throw vertical Smith-Vaile type.

Preparations are being made, and will soon be completed, for the erection of two electrically-driven shaft-pumps of 15 brake-horsepower. The motors will be of the same type as the haulage-motors. The pumps will be of the three-throw horizontal type, 4 inches in diameter by 6 inches stroke. The vertical lifts will be 381 feet and 570 feet respectively.

A steam pump is placed in the Pemberton mine, near to the shaft-bottom, for forcing water to the surface-reservoirs. The steam-cylinders are 16 inches in diameter by 30 inches stroke, and the pump-rams, 6 inches in diameter by 30 inches stroke, are double-acting. The speed is about 10 revolutions per minute.

The surface-water is caught in the Sawney pit, and is pumped into the same water-reservoir, by means of an engine with a cylinder, 12 inches in diameter by 36 inches stroke, coupled to a pump-ram, 7 inches in diameter by 36 inches stroke, making 56 strokes per minute. The vertical head is 111 feet.

Electric Plant.—The power-plant, in a separate building, consists of two units, each of 250 brake-horsepower when

worked condensing; the condensing-plant has not yet been erected, but the plans are now completed.

There are two enclosed, inverted, vertical compound Bellis-and-Morcom engines, with two cylinders, and forced lubrication to all the bearings.

The three-phase Brown-Boveri generators are direct-coupled to the engine-shaft. The exciters are also worked on the same shaft. The speed of the engine is 400 revolutions per minute. The current has a pressure of 550 volts, and a periodicity of 40 cycles per second.

The current from these two units is used for driving the underground motors, a 2 brake-horsepower motor on the surface, which pumps the safety lamp-oil into a service-tank erected above the turning-shop at the end of the lamp-rooms, by means of a small three-throw horizontal pump, and drives, when required, a small wood-turning lathe. The same current lights the pit-eyes, shaft-sidings and motor-houses, and adjacent roads belowground. During coal-winding hours the current is also used for lighting the screens. All lighting is effected through transformers, which reduce the pressure from 550 to 230 volts. By means of change-over switches, the screens are lighted, when the continuous plant is running, by means of the continuous current from the 45 brake-horsepower plant situated in the fan-house. This dynamo is driven by a Ruston-Proctor vertical engine, by means of a leather-chain belt. The dynamo is wound for 230 volts, and the current is used for all arc-lamps on the surface, for lighting the offices, workshops and screens (when required), and for driving the lamp-cleaning machine motor of $\frac{3}{4}$ brake-horsepower and the booster for charging the safety-lamp lighting batteries.

Cables.—The cables from the three-phase plant switchboard to the shaft-bottoms are enclosed in haskinized wood-casing. The power-cables belowground are all three-core steel-tape armoured, and are suspended by leather thongs behind the bar-legs.

Working of Seams.—Eight seams are now being worked to the four pit-eyes, and all are worked on the longwall principle. No coal-cutters are as yet at work, but a three-phase Diamond

overhead coal-cutter of 30 brake-horsepower is now in course of construction. It will cut in the Hoo cannel on the top of the Pemberton Two-feet mine to a depth of 4½ feet. The machine is expected to be at work in October of this year; and if successful, other similar cutters will be introduced.

A Grant electrically-driven rock-drill is used for drilling the holes in a tunnel being driven through the measures, rising 1 in 3. It is driven by a three-phase Brown-Boveri motor of 5½ brake-horsepower.

Screening-plant.—The coals from both pits gravitate to one point, and are there raised by a creeper to a sufficient elevation to enable them to run to four tipplers. The coal passes from the revolving tipplers to shakers, and is sorted into the following classes:—No. 1: slack, nuts and round; Nos. 2, 3 and 4: slack, nuts or filberts (as required), and cobbles and round; and No. 4 is also fitted with a small side-shaker for making a smaller class of nuts. From the shaker, the coal passes to the picking-belts, each 50 feet long: and hence by means of a Swift-and-House scraper-lowering shute into the wagons.

The dust is taken from the slack, and delivered on a canvas belt, which carries it on to a reversible belt, and this in turn delivers the dust to the north or south pit boiler elevator belt, as required.

Any small coal made on the belts, in passing over the belt-end screens, falls upon a suspension-belt fixed under the screen-stage and over the various lines of wagons and at right angles thereto, from which it is delivered upon the reversible belt as above described.

The pickings from the coal are also placed upon the reversible belt, through small shutes, and, consequently, all coals used at the boilers are automatically carried thither by means of the various conveyor-belts.

The dirt wound from the pits is taken to the dirt-tip by means of an endless-rope haulage, worked by the screening-engine and controlled by a separate clutch. This engine has two cylinders, each 12 inches in diameter by 30 inches stroke, making 84 revolutions per minute.

Each belt, each lowering-shute, each shaker and each creeper, is controlled by means of its own clutch.

NEW MOSS COLLIERY.

There are two shafts with horizontal tunnels to the Saltpetre and Black mines, worked at depths of 2,700 to 3,300 feet. An exploration-tunnel at a depth of 1,359 feet, and a staple-pit, 300 feet deep, proved a fault, with a throw of 1,245 feet, and the Roger and Great mines. There is a level-tunnel, at a depth of 1,530 feet, to the Roger mine on the west of the shafts; and a level-tunnel, at a depth of 2,268 feet, to the Roger mine on the east of the shafts. The Roger mine, 5 feet thick, is being worked by the longwall method, at depths varying from 1,410 to 2,580 feet.

No. 1 Shaft.—No 1 shaft is 2,820 feet deep and 16 feet in diameter, and at present coal is wound from the mouthing at a depth of 1,530 feet. The horizontal winding-engine, with two cylinders 36 inches in diameter by 5 feet stroke, is fitted with Daglish cut-off gear and a drum 16 feet in diameter. Locked-coil ropes, 4¼ inches in circumference, are used. The cage, with three decks, carrying six tubs and 3 tons of coal, is wound from a depth of 1,530 feet. The wrought-iron headgear is 80 feet high, and the pulleys are 16 feet in diameter.

There are ten steam-boilers, five working at a pressure of 120 pounds per square inch, and five at 65 pounds per square inch. The Green economizer has 704 pipes.

The hauling-engine, with two cylinders, 26 inches in diameter by 4½ feet stroke, is geared 9 to 1, and drives two strap-ropes, 4,275 feet long, for the north and south brows respectively.

The north-brow drum, with a strap-pulley, 10 feet in diameter, and a brow-pulley, 8 feet in diameter, hauls 600 tons of coal per day up a brow, 2,980 feet long, and at an average inclination of 1 in 3 or 19 degrees. The approximate load of coal on the rope is 21 tons. The rope runs under the tubs (each holding 10 cwts.) spaced, in sets of three tubs, 210 feet apart.

The south-brow drum, with a strap-pulley, 10 feet in diameter and a brow-pulley, 8 feet in diameter, hauls 700 tons of coal per day up a brow, 1,680 feet long, and at an average inclination of 1 in 5 or 11½ degrees. The approximate load of coal on the rope is 14 tons. The rope runs under the tubs (each holding 10 cwts.) spaced, in sets of three tubs, 120 feet apart.

A compressor, with two air-cylinders, 21 inches in diameter and steam-cylinders, 22 inches in diameter and 4 feet stroke, supplies compressed air to several underground winches employed to haul up short brows and along the levels.

A direct-current generator, driven by a horizontal engine, with a cylinder 16 inches in diameter by 3 feet stroke, produces 318 ampères at a pressure of 220 volts, or 70 kilowatts, when running at 500 revolutions per minute. The current is supplied to seven motors applied to pumps, 16½ and 17 kilowatts; a chain, 17 kilowatts; a winch, 6 kilowatts; a hammer, 14 kilowatts; a small dynamo, 20 kilowatts, etc.

The No. 1 pit-bottom is protected with side walls and steel girders. There is a lowering table to load the cages at the bottom, independently of the surface-loading.

No. 2 Shaft.—The No. 2 shaft is 2,850 feet deep and 16 feet in diameter; and at present coal is wound from the mouthing at a depth of 2,301 feet.

The horizontal winding-engine, with two cylinders, 36 inches in diameter by 6 feet stroke, is fitted with the Melling-Corliss valve and cut-off gear, and a drum, 18 feet in diameter. Locked-coil-ropes, 4½ inches in circumference, are used. The cage with four decks, carrying eight tubs and 4 tons of coal, is wound from a depth of 2,301 feet in 55 seconds. The wrought-iron headgear, is 90 feet high, and the pulleys are 16 feet in diameter.

There are two Lancashire boilers, 9 feet in diameter and 30 feet long, working at a pressure of 120 pounds per square inch. The Green economizer has 256 pipes. A Sirocco fan with a steel chimney, 70 feet high, is used in lieu of a high brick-built chimney.

The No. 2 pit-bottom is protected with side walls and steel girders, and wrought-iron plates are used instead of arching. An improved lowering-table and balance is used suitable for a four-decked cage.

Screens.—There are six picking-belts, two conveyors and three shaking-screens.

Workshops.—The workshop, 168 feet long by 38 feet wide, is fitted with a travelling crane, and the machinery is driven by

a horizontal engine, with a single cylinder 13½ inches in diameter and 22 inches stroke. The shops are fitted with lathes, a pneumatic hammer, a planing-machine, and drilling, slotting, shaping and other machines. There are six blacksmiths' hearths.

PENDLETON COLLIERY.

Pendleton colliery is situated in Pendleton, near Manchester. The colliery is a very old one; the sinking of the present two shafts was commenced in 1837, and the Albert and Crumbouke mines were reached in 1840.

During the sinking, cast-iron tubbing was inserted where the shaft passed through the old workings in the Worsley Four-feet mine, but in 1843 this tubbing proved too weak to resist the pressure against it, and the water broke in and drowned out the colliery. A powerful pumping-plant was erected, the quantity of water pumped being 2,330 gallons per minute; and ultimately the water was successfully tubbed out, and the getting of coal was resumed about the end of 1846. The large expenditure, however, incurred in overcoming the difficulties had so crippled the then proprietor that the colliery was stopped in 1848. It was acquired by Messrs. Knowles in 1852, and has since been continuously worked.

The pits were originally sunk each 8 feet in diameter: the winding-engine being between them, with one rope in each pit. One pit was used as an upcast, the ventilation being effected by a furnace and underground boilers. In consequence of the original tubbing having failed, the upcast pit was relined in 1871, reducing the diameter of this pit to 7 feet 2 inches for a depth of about 480 feet below the surface. The depth of the shaft to the Rams mine is 1,545 feet and all the workings lie on the dip side. From the shaft, an engine-plane is driven on the full dip of the mine to a distance of about 5,580 feet, the coal below this being won by east and west subsidiary inclined planes. The vertical depth below the surface at which coal is now being worked varies from 3,000 feet to 3,500 feet.

The seam, dipping about 1 in 3, is worked on a modified system of longwall, the modification being requisite in consequence of the steep dip.

The colliery has been entirely remodelled within the last 20 years, and practically all the machinery both on the surface and underground has been erected within that time.

The vertical winding-engine at the No. 1 pit has two cylinders, 32 inches in diameter and 72 inches stroke, with a plain cylindrical drum, 20 feet in diameter. There are two cages, each carrying six boxes of coal.

The No. 2 or upcast shaft is used for ventilation only. The Walker ventilating-fan, 18 feet in diameter and 5 feet wide, is driven by rope-gearing from a horizontal engine with a cylinder, 19 inches in diameter and 36 inches stroke, and an independent condenser.

There are six Lancashire boilers, 30 feet long by 8 feet in diameter, fitted with Henderson self-cleaning firebars, working ordinarily at a pressure of 80 pounds per square inch.

To supply power underground, there is a Walker air-compressing engine with two steam-cylinders each 38 inches in diameter, and two air-cylinders each 40 inches in diameter and 6 feet stroke, with an independent condenser: the air-pressure being 65 pounds per square inch.

There is in course of erection an additional Walker air-compressing plant, with compound steam-cylinders, the high pressure being 28 inches and the low pressure 52 inches in diameter, with two-stage air-compressing cylinders, 51 inches and 31 inches in diameter respectively, and 5 feet stroke. This plant will be supplied with steam by five double-flued Lancashire boilers, 30 feet long by 8 feet in diameter, fitted with a Green economizer.

The screens are of the jigger-type, with the usual picking-belts loading direct into canal-boats.

The underground machinery comprizes a hauling-engine, hauling up the main engineplane, with two cylinders each 20 inches in diameter and 42 inches stroke, and two drums each 6 feet in diameter. At the subsidiary brows, there are self-contained hauling-engines, that at the west brow having two cylinders each 16 inches in diameter; and that at the east brow, two cylinders each 10 inches in diameter. The level hauling is on the endless-rope quick-travelling system. The signalling is electrical.

The surface-works are lighted by electricity.

THE LANCASHIRE ELECTRIC POWER COMPANY.

The Lancashire Electric Power Company was formed for the distribution of power throughout the whole of Lancashire, south of the river Ribble, excepting the areas of Liverpool, Bootle, Manchester, Salford, Stockport, and the 2½ miles radius from Bolton town-hall. The mains for carrying current are being laid in duplicate, partly underground, laid in solid bitumen with steel-wire armouring and leaden sheathing for protection, the insulation being paper. The section of copper is 0·1 square inch, three conductors being enclosed in each cable. On another part of the way, the cables are being carried overhead on insulators, the same section of copper being used.

The current is delivered to the mains at a pressure of 10,000 volts on the three-phase alternating system. In the case of large users, the current is taken direct into the consumers' premises, and is there converted to a suitable pressure for use. In the case of small users, a supply is given in bulk to the township authorities, who act as distributors of the current. The distribution is both on the three-phase and direct-current systems, diverse conditions causing it to be advisable to use direct in some cases and alternating in others.

The generating-station is located in Radcliffe, on the banks of the river Irwell, near the Ringley-road station, on a site with an area of 20 acres. The first section of building erected consists of a boiler-house and an engine-room.

The boiler-house contains six Babcock-and-Wilcox water-tube boilers, fitted with chain-grate stokers, each giving an evaporation of 20,000 pounds of water per hour, at a working pressure of 150 pounds per square inch. The boilers are fitted with Babcock internal superheaters, and have a heating surface of 5,800 square feet. The boilers are placed in two rows of three each, face to face, with a firing alley-way between. Above this alley-way are the coal-bunkers, one bunker feeding two opposite boilers. The buildings being situated some 76 feet below the railway-level, the coal is fed by gravity into the bunkers from the railway-siding. The water is fed to the boilers from two Hall feed-pumps, each capable of delivering 12,000 gallons of water per hour. The make-up water is obtained from the town mains. Steam from the boilers is taken in a ring-main in the boiler-house, from which connections are taken to each of the machines.

The smoke-stacks are two in number, one for each set of three boilers. They consist of a base of 12 feet; and a steel shell, 150 feet high; they are lined with fire-brick to a height of 112 feet, the internal diameter being 10 feet.

There are four machines, each driven by vertical Curtis turbines, the alternators, each of 1,500 kilowatts, being placed above the turbine and on the same spindle. They run at 1,000 revolutions per minute, 11,000 volts, and give a three-phase current at 50 periods per second. The machines have an overload capacity of 50 per cent. for ½ hour, and of 100 per cent. for a momentary overload. There are four stages of expansion in the turbines, and the vacuum is about 28 inches throughout. One of the interesting parts of this turbine is the method of supporting the footstep-bearing: the spindle rotates in a cup, through the centre of which water is pumped at a pressure of 400 pounds to the square inch, thereby forming a thin skin of water which keeps the spindle from the face of the cup. This water-skin is about 0·001 inch thick. The water is raised to this high pressure by means of two three-throw pumps, each driven by a motor of 7½ horsepower, and rotating at 15 revolutions per minute: one of them being a stand-bye. The water-accumulator has sufficient capacity to provide water for all the turbines for ¼ hour should the pumps fail for any reason. Each turbine is connected directly to a vertical Mirrlees-Watson surface-condenser, each capable of dealing with 30,000 pounds of steam per hour, and having a cooling-surface of 3,500 square feet. The Edwards three-throw air-pumps are motor-driven, at a speed of 160 revolutions per minute. Circulating water is taken from the river by means of four Gwynne centrifugal circulating pumps, each capable of delivering 160,000 gallons per hour against a head of 26 feet. The pumps are primed by a dry-air pump, the vacuum being maintained by means of gravity by using a tank placed higher than the water-barometer. This pump is also used as a means of increasing the vacuum in the condensers, by equalizing the flow of circulating water. An overhead travelling-crane, capable of lifting 25 tons, is actuated by motors: the span being 47½ feet and the total lift 39½ feet.

The alternators are excited by means of separate exciter-sets, three in number, each of 150 kilowatts, consisting of Allans engines with British Thomson-Houston dynamos, running at

420 revolutions per minute and a pressure of 220 volts. The engines are run non-condensing, the exhaust-steam passing through a heater for the boiler feed-water.

The switchboard is mounted on a gallery, and is of the remote-control type. The main switches are operated by motors controlled from the main switchboard, upon which only low-tension current is taken. There are two sets of omnibus bars, divided by a sectionalizing switch. The switchboard consists of panels, each generator and each circuit having a panel to itself. The generator-panel has a voltmeter, an ammeter, and a power-factor indicator, together with the necessary trip-switches for operating the motors. Each feeder-panel has an ammeter and a wattmeter. Besides these, there is a low-tension board for operating the auxiliary plant in the station.

There is an electric locomotive crane capable of lifting 10 tons, and it can be used for shunting and other work on the siding.

MANCHESTER CORPORATION ELECTRICITY-WORKS, STUART STREET.

System.—Three-phase alternating currents, with a frequency of 50 cycles per second, are generated at the main power-house at the extra high-pressure of 6,500 volts, and are transmitted at this pressure to the sub-stations. The current from the sub-stations is supplied at a pressure of 500 to 550 volts to the tramways, and at 420 and 210 volts for lighting and power-purposes.

Coal-supply.—A special railway-siding connects the Stuart Street works with the Lancashire and Yorkshire railway. The railway-trucks are emptied direct into coal-hoppers on the siding, and thence the coal is carried by electrically-driven conveyors to the bunkers over the boilers. The coal is weighed before it is deposited in the main hoppers, and it will also be automatically weighed and recorded by means of measuring-boxes attached to the shoots leading to the boiler-furnaces.

Buildings.—The buildings consist of two boiler-houses, chimneys, pump-rooms and engine-houses. They are of steel framework, filled in with brick-walls, faced with white-ended bricks and dressings of Ruabon bricks and Yorkshire stone.

Boilers.—There are twenty-four double-drum Babcock-and-Wilcox water-tube boilers, each capable of evaporating 12,000 pounds of water per hour at a pressure of 170 pounds per square inch; and twelve Babcock-and-Wilcox water-tube boilers, each capable of evaporating 20,000 pounds of water per hour at a pressure of 200 pounds per square inch.

Feed-pumps.—City water is used. Three Weir compound duplex steam-pumps are each capable of delivering 15,000 gallons of water per hour against a steam-pressure of 170 pounds per square inch.

First Engine-room.—There are six main three-phase alternator sets of 1,500 kilowatts each. There are four overhead electrically-driven travelling-cranes of 20 tons capacity.

Each of the main engine-sets consists of a Yates-and-Thom vertical cross-compound engine of 2,500 indicated horsepower, running at 94 revolutions per minute; and a three-phase alternator of 1,500 kilowatts, generating current at a pressure of 6,500 volts with a periodicity of 50 cycles per second. The high-pressure and low-pressure cylinders of the engine are 36 inches in diameter and 71 inches in diameter respectively by 3½ feet stroke. The cylinders are steam-jacketted, and are fitted with Dobson-Corliss valve-gear. The main shaft is 22 feet long and 25 inches in diameter in the main bearings. The cast-iron fly-wheel, built up in four sections, weighs about 70 tons. The generator is placed between the high-pressure and low-pressure cylinders, and is of the revolving-field type, the pole-pieces being mounted on the external periphery of the fly-wheel of the engine and revolving in the stationary armature, with star-connected windings.

A special feature in connection with the regulation of the speed of these engine-sets is that the engine-governor can be controlled from the switchboard-gallery by means of an electric motor. The barring-gear for starting the engines is also electrically driven.

Second Engine-room.—There are two triple-expansion engines of 6,500 horsepower, and two three-phase alternator sets of 3,750 kilowatts.

All the engines are run condensing, and cooling-towers are erected for the purpose. The engines develop a total of 28,000 horsepower.

Switchboards.—Two main high-tension switchboards are each arranged to control three high-tension three-phase generators, one high-tension three-phase motor and seven high-tension feeders; and another main switchboard controls the two main sets of 3,750 kilowatts, etc.

Cable-subway.—The cable-subway accommodates 30 three-core cables, distributors, etc. The cables are carried on brackets fixed on each side of the subway. The subway is 10 feet high, 5 feet wide and 2,820 feet long.

Cables.—About 170 miles of cables are required for connecting the sub-stations with the generating-station.

THE VICTORIA UNIVERSITY OF MANCHESTER: THE MANCHESTER MUSEUM.

The museum takes cognizance of natural history in a wide sense, with special reference to mineralogy, geology, zoology and botany, without, however, excluding such subjects as archæology and anthropology. The nucleus of the present museum was furnished by the collections formerly belonging to the Manchester Natural History Society, founded in 1821, and by those of the Manchester Geological and Mining Society, founded in 1838.

The special geological and palæontological collections comprize:—The "David Forbes" collection of minerals and rock specimens; the "Waters" collection of fossils; the "Boyd Dawkins" collection of fossils, minerals and prehistoric remains; the "Williamson" collection of Yorkshire fossils and specimens of coal; the "Cash" collection of sections of Carboniferous plants; the "Kay-Shuttleworth" collection of Carboniferous fossils; the "Hick" collection of sections of Carboniferous plants; the "George Wild" collection of Carboniferous fossils; the "Melvill" collection of Eocene mollusca; the "Darbishire" collection of Tertiary shells, from the raised beach

at Uddevalla; the "Cairns" collection of fossils, chiefly from the Crag, the Cretaceous and the Carboniferous Limestone; the "Bird" collection of fossils; the "Toulmin Smith" collection of Cretaceous sponges; the "Lightbody" collection of fossils; and the "Manning" collection of fossils.

THE MANCHESTER SHIP-CANAL.

The entrance to the Ship-canal at Eastham is 19 miles from the bar at the mouth of the river Mersey, and the access is from the sea *via* the lower estuary. The access-channel has been excavated to a depth of 20 feet below the Old Dock-sill, Liverpool, so as to give access to the canal at any state of the tide. The canal is 35½ miles in length, and the principal docks are at Manchester, a distance of 50 miles from the sea.

The canal between the entrance at Eastham and the docks at Manchester has been excavated throughout to a depth of 26 feet, which depth is maintained by dredging, but in the tidal portion of the canal between Eastham and Latchford (21 miles), the available depth varies from 26 feet to 33 feet, according to the state of the tide. The bottom-width at the full depth is 120 feet, with the following exceptions:—(*a*) At the curve at the Weaver outfall, the width at the full depth is 180 feet; and at the bend at Runcorn, approaching the Runcorn railway-bridge, the width is 150 feet. (*b*) For a part of the length between Latchford locks and Partington coal-basin (about one mile in all), the bottom-width is at present only 80 to 90 feet, and large vessels are not allowed to pass each other on that portion of the canal. (*c*) From Barton aqueduct to the Manchester docks, the bottom-width is 170 feet.

The tidal portion of the Ship-canal, from Eastham to Latchford locks, or 21 miles, is maintained at 14 feet 2 inches above the level of the Old Dock-sill, Liverpool (or 9 feet 6 inches above Ordnance datum, or mean sea-level), giving a depth of 26 feet of water.

The three locks at Eastham form three separate entrances, which are open to the river-level, whenever the tide rises more than 14 feet 2 inches above the level of the Old Dock-sill, and when the tide is below this level, access is obtained by means of the locks.

The lower sill of the large lock (600 feet by 80 feet) is 23 feet below the Old Dock-sill, the upper sills of all the large locks being 28 feet below the normal water-level. A vessel can be passed through the largest lock in 8 minutes or less. The intermediate lock is 350 feet long by 50 feet wide, and the small lock, 150 feet by 30 feet. The width of the canal at Eastham locks is 315 feet.

Mount Manisty, on the north side of the canal, was formed by the material excavated from the rock-cutting during the construction of the canal, and is available for ballasting vessels.

The dimensions of the Manchester Docks are:—No. 1, 700 feet by 120 feet; No. 2, 600 feet by 150 feet; No. 3, 600 feet by 150 feet; No. 4, 560 feet by 150 feet; No. 5, 980 feet by 750 feet; No. 6, 850 feet by 225 feet; No. 7, 1,160 feet by 225 feet; No. 8, 1,340 feet by 250 feet; and No. 9, 2,700 feet by 250 feet. The dock-equipment includes 52 hydraulic, 57 steam and 81 electric cranes, with a radius of from 16 to 40 feet, capable of lifting from 1 to 10 tons to a height from rail-level of from 13 to 59 feet; a 30 tons steam crane; 35 locomotives; 6 floating pontoons of a dead-weight capacity of 800 tons each, and all modern appliances for giving quick despatch to vessels. There is also a pontoon-shears capable of dealing with weights up to 250 tons, with a lift of 21 feet.

There is a range of thirteen single-floor, one two-floor, six three-floor, five four-floor, and twelve five-floor transit-sheds, fitted with modern appliances; also thirteen warehouses, seven storeys each, fitted with 27 friction-hoists worked by gas-engines; and in Trafford Park, four single-floor warehouses, each 300 feet by 100 feet. The docks, quays, sheds and warehouses, are lighted by electricity, and there are 34 hydraulic and 16 electric capstans on the quays. Bonded accommodation is also provided.

The total traffic since the opening of the canal in 1894 has been as follows:—1894, 925,659 tons; 1895, 1,358,875 tons; 1896, 1,826,237 tons; 1897, 2,065,815 tons; 1898, 2,595,585 tons; 1899, 2,778,108 tons; 1900, 3,060,516 tons; 1901, 2,942,393 tons; 1902, 3,418,059 tons; 1903, 3,846,895 tons; and 1904, 3,917,578 tons.

BRITISH WESTINGHOUSE ELECTRIC AND MANUFACTURING COMPANY, LIMITED: TRAFFORD PARK WORKS, MANCHESTER.

The British Westinghouse Company own about 150 acres of land at Trafford Park; 55 acres of this are enclosed within the buildings, while 32 acres are roofed in. There are altogether nine main buildings, including the offices. The machine-shop, 1,000 feet long by 430 feet in width, is divided into five bays; next to this is the steel-foundry; beyond which is the brass and malleable-iron foundry, with pattern-shop and stores. There is a box-factory and a paint-shop on the right of the machine-shop. A noticeable feature of the works is the excellent lighting and ventilation.

The principal machine-shop is divided into five bays, and the whole structure is of steel. The largest lathe will take in work 125 inches in diameter, while the length between the centres is 45 feet. There are 10 feet to 28 feet boring-mills, 10 feet to 14 feet planing-machines, large radial drills, a three-spindle vertical milling-machine and double-headed two-spindle horizontal boring-machines.

In the steel-foundry, there are 20 tons open-hearth Wellman-Seaver rolling-furnaces of the most recent design; two 50 tons and one 10 tons overhead electric travellers; five air-hoists and jib-cranes; cutting-saws; annealing and drying ovens; and other usual appliances. The laboratory-arrangements are complete, chemical and mechanical tests being carried out in the usual way. There is a 100,000 pounds testing-machine.

The iron-foundry is somewhat larger than the steel-foundry. There are two Whiting cupolas, with special weighing machinery, by which the proper mixture of pig is obtained. The cupola-blast is generated by two Sturtevant blowers, driven by an induction-motor. Iron-castings, up to 30 tons in weight, are made.

In the boiler-house, there are six Babcock-and-Wilcox boilers, each having 4,020 square feet of heating-surface, steam being generated at a pressure of 160 pounds per square inch. These boilers are mechanically fired by Roney stokers, driven by a Westinghouse steam-engine. There are three air-compressors of great capacity.

The tunnel under the machine-shop is extended to the foundries and pattern-shop.

Electrically-driven cranes are used throughout the works; and electricity is the chief motive power. In the large machine-shop, there are four 50 tons cranes, seven 10 tons cranes, and five 5 tons cranes. There are two 20 tons cranes in the transformer department. In each of the main aisles of the steel- and iron-foundries are two 50 tons cranes and four 10 tons cranes.

A Westinghouse single-phase electric railway runs round the works.

MESSRS. W. T. GLOVER & COMPANY, LIMITED.

Almost every type of cable was shown in the process of manufacture, including cables for colliery and mine working.

The main building, consisting of six large parallel bays, contains large stranding-machines capable of laying up in one operation as many as 91 strands of wire, papering machines for putting on the wellknown Diatrine insulating-paper, laying-up machines for the purpose of cabling up several cables into one multicore cable, armouring machines, etc. There are several large hydraulic lead presses, capable of covering cables up to 4 inches in diameter: the lead being forced on while in a semi-plastic state through cores and dies.

The test-tanks and testing machinery are capable of applying pressures up to 72,000 volts on the cables. The Claremont hydraulic testing-tank is used to test the "waterproofness" of the lead-covered paper cables, pressures being applied, up to 100 pounds per square inch, to the cable under water. In the various large outbuildings are installed forcing machines for the manufacture of bitumen-cables, paper-serving machines, machines for covering wires and cables with rubber, and an indiarubber-mill, for the cleaning and drying of raw indiarubber and the mixing and calendering of the various indiarubber-compounds used in vulcanized indiarubber-cables.

The whole of the machinery is electrically driven.

THE INSTITUTION OF CIVIL ENGINEERS.

EDUCATION AND TRAINING OF ENGINEERS.

REPORT OF A COMMITTEE* APPOINTED BY THE COUNCIL OF THE INSTITUTION OF CIVIL ENGINEERS ON NOVEMBER 24TH, 1903.†

We have the honour to submit the following report and recommendations for the consideration of the Council of the Institution of Civil Engineers, in accordance with the terms of reference to this Committee, which was appointed "To consider and report . . . . as to the best methods of training for all classes of engineers, including both scholastic and subsequent technical education; it being an instruction to this Committee that the principle shall be maintained that the education of an engineer must include both practical experience and scientific training."

It is desirable to place on record, at the outset, a brief account of the circumstances under which the Committee was appointed, by unanimous resolution of the Council, on November 24th, 1903.

In taking this action, the Council of the Institution of Civil Engineers proceeded on lines which had been followed for a long period, with a view to improvement in the training and status of civil engineers.

An exhaustive inquiry had been made in 1868 into then existing conditions and systems of engineering education in the United Kingdom and in foreign countries; and the results of this inquiry were published by the Institution in 1870. In 1891, another statement was published dealing fully with the facilities for engineering education afforded at that date by the engineering schools of universities and colleges in the British Dominions.

* A Report adopted by the Council of the Institution of Civil Engineers, April 2 th, 1906.

† Members of the Committee:—Sir William H. White, K.C.B., D.Sc., LL.D., F.R.S., Chairman; Archibald Barr, D.Sc.; Sir John Wolfe Barry, K.C.B., LL.D., F.R.S.; Sir Alexander R. Binnie; Alexander Gracie; Robert Kaye Gray; Harry E. Jones; Sir Alexander B. W. Kennedy, LL.D., F.R.S.; Henry Louis, M.A.; A. T. Tannett-Walker; R. L. Weighton, M.A.; and J. Hartley Wicksteed.

The education qualifications required of candidates for admission as students in 1889, and subsequently the system of examinations established in 1897 for students and associate members of the Institution of Civil Engineers, furnished further proof of the importance attached by the Council to the higher education of civil engineers.

During the year 1903, renewed discussions of this subject took place at the Engineering Conference of the Institution of Civil Engineers, and at meetings of the Institution of Mechanical Engineers, the Institution of Naval Architects, and important engineering societies outside London. These discussions showed wide differences of opinion as to the best methods of training engineers, but indicated a general feeling in favour of thorough investigation of the subject by some body representing all branches of engineering, whose conclusions would command the attention of all who were interested in the education and training of engineers. This general desire was definitely expressed in a letter (of May 8th, 1903) addressed by the President of the Institution of Mechanical Engineers to the President of the Institution of Civil Engineers, stating that the Council of the former society considered it desirable that a representative Committee should be appointed by the Council of the Institution of Civil Engineers to consider and report on the whole subject of engineering education. This suggestion was the immediate cause of action by the Council of the Institution of Civil Engineers (November, 1903) after the summer vacation, when steps were taken to appoint the Committee whose work is now completed.

The Council then decided to request the engineering societies named below to assist the proposed inquiry by nominating representatives to serve thereon:—The Institution of Mechanical Engineers; the Institution of Naval Architects; the Iron and Steel Institute; the Institution of Electrical Engineers; the Institution of Gas Engineers; the Institution of Engineers and Shipbuilders in Scotland; the Institution of Mining Engineers; and the North-east Coast Institution of Engineers and Shipbuilders.

All these institutions complied with the request, and nominated representatives, and the constitution of the Committee was completed in February, 1904, as under:—

Sir WILLIAM H. WHITE, K.C.B., D.Sc., LL.D., F.R.S., Past-President Inst.C.E., *Chairman.*

The PRESIDENT of the Institution of Civil Engineers (*ex officio*)

Sir JOHN WOLFE BARRY, K.C.B., LL.D., F.R.S., Past-President Inst.C.E.

Sir ALEXANDER B. W. KENNEDY, LL.D., F.R.S., Vice-President Inst.C.E.

J. HARTLEY WICKSTEED, M.Inst. C.E. (*representing the Institution of Mechanical Engineers*).

ALEXANDER GRACIE, M.Inst.C.E. (*representing the Institution of Naval Architects*).

Sir EDWARD CARBUTT, Bart.,* M.Inst.C.E. (*representing the Iron and Steel Institute*).

R. KAYE GRAY, M.Inst.C.E. (*representing the Institution of Electrical Engineers*).

HARRY E. JONES, M.Inst.C.E. (*representing the Institution of Gas Engineers*).

Prof. ARCHIBALD BARR, D.Sc., M.Inst.C.E. (*representing the Institution of Engineers and Shipbuilders in Scotland*).

Prof. HENRY LOUIS, M.A. (*representing the Institution of Mining Engineers*).

Prof. R. L. WEIGHTON, M.A. (*representing the North-East Coast Institution of Engineers and Shipbuilders*).

J. H. T. TUDSBERY, D.Sc., M.Inst.C.E., *Secretary.*

J. G. HENDERSON, B.Sc., Assoc.M.Inst.C.E., *Assistant Secretary.*

As the members of the Committee were busily occupied and widely scattered over the country, it was felt from the first that much of the work must be done by correspondence, and that it would be advantageous before meetings took place to settle the heads under which the inquiry might be arranged most conveniently. For that purpose the following memorandum was prepared and circulated by the Chairman to the members of the Committee.

PROPOSED SECTIONS OF INQUIRY.

1. *Preparatory Education in Secondary Schools;* with special reference to suitable training of youths who are intended for the engineering profession in mathematics, elementary science, modern languages and handicrafts.

2. *Training in Offices, Workshops, Factories or on Works;* including the decision as to the period or periods at which such training can best be given, its character and duration. The possibility to be considered of giving to the preliminary stages of this practical training as broad a character as possible, so as to prepare students for any branch of engineering they may subsequently enter.

* On the regretted death of Sir Edward Carbutt, in October, 1905, Mr. A. T. Tannett-Walker, M.Inst.C.E., was appointed to serve on the Committee as a representative of the Iron and Steel Institute.

3. *Training in Universities and Higher Technical Institutions:* opinions to be formed as to:—(*a*) The most suitable age at which average students could begin this course. (*b*) The possibility of arranging the earlier courses of study so as to be common to all branches of engineering. (*c*) The duration of such common courses of study; and (*d*) the extent to which specialization should be provided for in technical institutions, and the extent to which it should be carried.

4. *Post-graduate Work:* how it can best be organized and maintained:—(*a*) At universities and higher technical institutions; and (*b*) on actual works, and in mines, factories, etc.

At the first meeting of the Committee (held on February 24th, 1904) this memorandum was approved, and it was decided to entrust detailed consideration of the first section (preparatory education in secondary schools) to a Sub-committee consisting of Sir Alexander Kennedy (Chairman), Professors Archibald Barr, Henry Louis and R. L. Weighton, and Mr. Alexander Gracie. It was further agreed that the Committee, as a whole, should undertake the consideration of (*a*) practical training in offices, workshops, factories, or on works; and (*b*) training in universities and higher technical institutions.

In prosecuting their enquiries, the Committee thought it essential to obtain, either orally or in writing, the opinions of persons having experience in engineering education, and of eminent engineers practising in various branches of the profession. It was desired to make this record of opinion precise, representative and comprehensive; for which purpose members of the Committee undertook to suggest the form in which inquiries should be framed, to give the names of those to whom application might be made, and to indicate general detailed action, which, in their judgment, would be of value in the collection of opinions and information. These suggestions were summarized and condensed, under the supervision of the Chairman, by the Secretary and Assistant-secretary. The schedules of questions approved by the Committee and subsequently issued were prepared on this basis.

These preliminaries necessarily occupied a considerable time and entailed a large amount of correspondence. Their final result has been the attainment of both definiteness and wide range in the questions circulated; and has secured the collection of a great body of opinion from representative engineers in active practice, professors and teachers in technical colleges and universities, and others whose advice has been of value in reaching a decision on matters referred to the Committee. The scope of their inquiry

was necessarily extensive, and the Committee desire to express their gratitude to the large number of gentlemen who have favoured them with advice and opinions. They recognize that those who have given assistance are actively engaged in educational and professional work, which made it no easy matter to devote attention to the questions asked. On the other hand, the numerous and full responses made by men whose experience gives authority to their opinions and recommendations, have enabled the Committee to proceed with greater certainty in framing their report. Diversities of opinion have been disclosed in regard to some details, as was inevitable from the nature of the subjects: but in all main features of their recommendations the Committee have support from the large majority of their professional colleagues and of the teachers in universities and higher technical institutions. This fact cannot fail to carry great weight with those for whose benefit the report has been prepared.

The Committee are of opinion that it would not have been possible in any other way to have secured equally full consideration of the subject, or so valuable a mass of information and opinion in regard to the principles it is desirable to follow in training engineers. More time and labour have been involved by adopting the method of written communication instead of oral evidence: but a much larger number of men has been reached, and the final result is more satisfactory.

I. Inquiry as to Preparatory Education (*See Appendix I.*).

The details of this portion of their work were entrusted by the Committee to the above-mentioned Sub-committee. A schedule of the questions issued by the Sub-committee will be found in Appendix I., which also contains an analyzed summary of the replies. This schedule was issued to 120 representatives of the following classes:—(1) Teachers in engineering colleges; (2) headmasters of secondary schools at which it is believed special attention is paid to scientific training; and (3) engineers not engaged in teaching. Replies were received from 80 per cent. of the gentlemen whose opinions were invited; and from these replies definite conclusions were deduced as to the prevalent opinions on points raised by the questions.

The report which the Sub-committee submitted to the main Committee was considered at a meeting held on March 23rd, 1905, and was then approved and adopted.

The following are accordingly the recommendations of the Committee in respect of the most suitable preparatory education for boys who are intended to become engineers:—

Recommendations in Respect of Preparatory Education.

1. It is desirable that a boy intended for the engineering profession should, before leaving school and commencing to specialize, have attained a standard of education equivalent to that required by the Institution studentship examinations; and that he should not commence his special training until he is about 17 years of age.

2. A leaving examination for secondary schools, similar in character to those already existing in Scotland and in Wales, is desirable throughout the United Kingdom. It is desirable to have a standard such that it could be accepted by the Institution as equivalent to the studentship examination, and by the universities and colleges as equivalent to a matriculation examination.

3. Advanced teaching of history and geography, with instruction and practice in essay-writing and in précis-writing, should be included in the ordinary school curriculum; and the instruction in English subjects should include at least an introduction to English literature.

4. Greek should not be required, but an elementary knowledge of Latin is desirable. The study of Latin should, however, be discontinued during the last two years of attendance at school, or after the standard required for the leaving certificate has been attained. Modern languages, especially French and German, should be studied and should be taught colloquially or in such a way as to give the pupils a practical knowledge of each language, sufficient to enable them to study its literature and to converse in it with some degree of facility.

5. Instruction in mathematics should be given by methods differing considerably from those usually adopted in the teaching of this subject merely as an intellectual exercise. The geometrical side of mathematics should be fostered, and before they leave school boys should be conversant with the use of logarithms, and, with at least the elements of trigonometry, including the solution of triangles. It is also of importance that instruction in practical arithmetic should be carried further than has been generally the case hitherto, with the object especially of encour-

aging the use of contracted methods and operations in mental arithmetic; and of encouraging also the expression of results with only such a degree of (numerical) precision as is consistent with the known degree of certainty of the data on which they are or may be supposed to be based.

6. It is preferable that boys should attain at school a general knowledge of elementary physics and chemistry, or of what is sometimes called "natural philosophy," rather than that they should pursue in detail some particular department of science.

7. Special attention should be given to drawing; the instruction should include ordinary geometrical drawing with orthographic projection, curve-drawing, freehand drawing, and practical mensuration.

8. Work in the nature of handicraft, such as carpentry or turning or elementary field-surveying, may be encouraged as a recreation but should not be required as a school exercise.

9. It appears to be impossible, in the general curriculum of school work, to include advantageously time for instruction in such a subject as surveying, which has been suggested.

The Committee recommend that this scheme of preparatory education should be officially communicated to the Board of Education and widely circulated amongst those engaged in the conduct of secondary schools and engineering colleges, in order that future schemes of tuition of youths who contemplate entry into the engineering profession may be guided thereby. The Committee are of opinion that if this course is taken it would assist in overcoming one great difficulty now universally felt in institutions in which applied science is taught. At present a considerable proportion of students enter technical institutions ill-prepared, and at least one year has to be devoted to instruction which ought to be secured beforehand. Proper preparation is essential if students are to derive full benefit from special instruction in applied science. Professors and teachers ought not to be required to undertake subjects that should be taught elsewhere, but should be left free to devote themselves to scientific and technical instruction, which is their real work.

II. Inquiry as to Engineering Training (*See Appendix II.*).

The Committee found it convenient to deal with sections 2, 3 and 4 of the inquiry together. These include training in offices, workshops, factories or on works, generally designated

"practical" training; training in universities and higher technical institutions; and post-graduate work. In these instances also, as explained above, a schedule of questions was framed (Appendix II.) and was circulated widely; but the Committee embodied in the schedule their conclusions on certain important subjects which had been thoroughly discussed by the members, and on which they were unanimous. In that course there was no interference with the free expression, by those whose opinions were solicited, of views contrary to those of the Committee; and the replies indicated clearly that this fact was realized. Nor were the comments of correspondents limited to points raised in the schedule. On the contrary, perfectly independent statements of opinion were submitted in many cases. The Committee desired primarily to ascertain the views of men whose opinions were entitled to respectful consideration, in consequence of their experience and study of education and of engineering training. In all instances, these communications have received due consideration by the Committee, after being carefully grouped and analyzed.

Each member of the Committee was at liberty to forward the names of gentlemen to whom schedules should be sent, and each institution was asked officially to suggest names, in order that the list might be made as complete as possible, and that each department of engineering might be adequately represented. The total number of schedules issued was 676, and the total number of replies received was 267. Their distribution over different branches of the profession may be classified roughly as follows:—

Branches of the Profession.	No. of Schedules issued.	No. of Replies received.
1. Engineers engaged in constructional work (railways, docks, harbours, canals, waterworks, sewerage, etc.)	34	16
2. Mechanical engineers	200	82
3. Mining engineers	72	22
4. Iron and steel manufacturers	47	16
5. Naval architects, shipbuilders and marine engineers...	119	32
6. Gas engineers	94	39
7. Electrical engineers	66	30
8. Professors, and others who are, or have been, engaged in teaching	44	30
Totals	676	267

The gentlemen whose opinions were asked were actively engaged in professional work, and in consequence there were

delays in making replies. Repeated applications were necessary before the inquiry could be completed, and it was decided finally to make November 1st, 1905, the latest date for the receipt of replies.

An analysis of the replies is given in Appendix II. From this it will be seen that the tentative suggestions and recommendations embodied by the Committee in their schedule have received very general support; this support has been given by each of the great sections of the engineering profession. A few correspondents expressed radically different views; but, in the main, the opinions of the Committee have been endorsed, and this result is satisfactory, since it indicates the possibility of practical effect being given to the recommendations. The Committee were not assisted so fully by replies to their question on mathematical teaching as to others; they therefore obtained specially the opinions of their colleagues engaged in tuition, and of other gentlemen who have large experience in this matter.

The Committee have had in view throughout what may be termed an "average boy," of ordinary ability, whose parents are in a position to secure for him a thorough training before he begins his actual professional work as an engineer. They recognize the necessity that will always exist for providing also suitable means of training for young men not so favourably situated, who work their way by sheer ability and force of character, and whose earlier careers do not permit of the methodic preparatory education and training which they consider best for the average boy. The Committee also recognize the certainty that other most valuable recruits for the engineering profession will continue to enter at a later period of life, and from other systems of education and employment. At the same time, it is obvious that, in all such cases, men may be trusted to find their way, and to avail themselves of existing opportunities for instruction and training. Their concern, therefore, has been with the best general scheme adapted to the average boy.

The Committee have not overlooked the established customs of universities and colleges to which engineering schools are attached, and have given weight to the necessity for arranging terms and courses of study with due regard to general efficiency in the conduct of these institutions. Consequently they do not recommend absolute uniformity of arrangement in college courses of study or in their method of association with practical

training; nor do they consider such uniformity necessary. In Scotland, it may be anticipated that the alternation of winter study at the universities with long summer vacations, usually spent in practical work, will be continued; whereas in England, the sessions and vacations will be arranged differently. Other varieties of practice exist or will be introduced; and, in the judgment of the Committee, considerable latitude is permissible in these matters without loss of educational efficiency.

Recommendations in Respect of Engineering Training.

The Committee desire to preface these recommendations by the statement that they are unanimous in the opinion that engineering training must include several years of practical work, as well as a proper academic training. Long experience has led to general agreement amongst engineers as to the general lines on which practical training should proceed; and it has, therefore, been unnecessary to deal at any great length with that matter in the recommendations. It must not be supposed, however, that the fuller treatment of academic training in the following pages indicates its greater relative importance; the reason for this fuller treatment is to be found rather in a desire to suggest courses of study which can be best associated with the practical training that is essential to engineering education.

Taking the schedule of opinions and questions relating to practical training (Appendix II.) as determining the order followed, the Committee make the following recommendations. The numbers refer to the sections of Appendix II.

1. The average boy should leave school when he is about 17 years of age. Much depends upon the development of individual boys, but the minimum age should be 16 and the maximum 18 years.

2. The practical training should be divided into two parts, whenever that arrangement can be made; and the preliminary stage of practical training should consist in all cases of at least a year spent in mechanical engineering workshops. This "introductory workshop course" is desirable even when students do not contemplate devoting themselves at a later stage to what is generally designated "mechanical engineering." Thus, for mining engineers, the machine shops of a large colliery would be found especially suitable. The Committee are supported in

this recommendation by the opinions expressed by a large proportion of the engineers who have been consulted. It is recognized that at present there are practical difficulties in arranging for this workshop year being interposed between the school and college work, and that employers may consider the arrangement objectionable in their interests. On the other hand, the Committee suggest that these difficulties should not be insurmountable; and the general agreement as to its advantageous effect on training leads them to hope that practical trial may be given to the suggestion. In any case, the Committee recommend that an "introductory workshop course" of at least a year should be included whenever possible in the practical training of all engineering students. Where the "introductory workshop course" is possible before the college training, it should not be less than one year, nor more than two years. The longer period may be desirable in the case of boys who are to become mechanical engineers, and useful in all cases, when boys leave school at 16 years. In some cases, it may be preferred to take the workshop course after the first year of the college training common to all branches of engineering. An interruption of college training at a later period must involve great disadvantages.

3. During workshop training, boys should keep the regular working hours, should be treated like ordinary apprentices, be subject to discipline and be paid wages.

4. Nothing should be done in the form of evening study which would impose undue strain upon the physique of boys. In some cases, this might prevent attendance at evening classes; but experience shows that many boys can attend such classes without physical injury and with great educational advantage. The Committee think it is most important that all boys should at least maintain their scholastic acquirements during the introductory workshop course, and, for the class of boys in question, it is considered that this result might be secured, by private tuition or otherwise, without undue physical strain. Nothing should be done to discourage boys, who so desire and are physically fit, from adding to their knowledge either by private study or by attendance at classes.

5. As a rule it is preferable to proceed to a technical college or university on the completion of the introductory workshop

course. This is advantageous to most boys, as it abridges the period between school and college, and lessens the danger of retrogression in knowledge. It also facilitates the arrangement of common courses of study for junior students in technical colleges and universities; and, on the whole, gives the students better opportunities of benefiting by college training.

In some cases—as for example when boys are intended to become mechanical engineers—it may be advantageous to complete the practical training before entering college; but, if this is done, it becomes more important that simultaneous education during practical training should be secured by private tuition or in evening classes; otherwise boys would lose seriously during four or five years' suspension of systematic study, and would be disadvantaged on entering college.

The alternation of college study and practical training is only feasible when (as in the Scotch universities) the college vacation practically occupies half the year; or in the case of mining engineers, where the official requirements under the Coal-mines Regulation Acts prescribe a minimum period of four months spent in mines before the termination of the college course.

6. For the average student, the period of college study should be three sessions, provided he is well prepared before entering college. In the case of students, who desire to follow up the science of their profession, a fourth year might be added, which would be in some cases post-graduate work, and might come after the practical training is completed. In cases where students are exceptionally well-prepared before entering college, or are above the ordinary age, or possibly without the means required for a full course of study, facilities should be given for shortening the course of study.

In all cases, the first session might be advantageously devoted to a common course of study by average students, and probably that common course might be extended into the second session without loss to final specialization.

7. A sound and extensive knowledge of mathematics is necessary in all branches of engineering, although some of these branches require more advanced mathematics in their practice than others. The capacity for acquiring mathematical knowledge varies greatly in individual students, and many who become

competent engineers have not the power of acquiring the higher mathematics. These differences of actual requirements and individual capacity must be recognized in courses of instruction, and can hardly be dealt with by any general statement.

It should be possible, however, for the student of average ability who, at his entry upon the study of applied science, has advanced to the stage of preparation in mathematics outlined in the foregoing recommendation as to preparatory training (see page 486) to master sufficiently, during the common course of instruction for all engineering students, the subjects included under the category of pure mathematics; provided the instruction proceeds in a systematic and well-considered manner.

The Committee endorse the practically universal recommendation, made by those whose special knowledge and experience entitle them to speak with authority, that a sufficient time should be allotted to the study of pure mathematics during the common college-course, to permit the best students to obtain a sound knowledge of algebra, trigonometry, analytical and practical plane geometry, the elements of solid geometry, and a working knowledge of the differential and integral calculus, and of the simpler differential equations. To this fundamental mathematical training, there must be added instruction in applied mathematics and mechanics. The extent to which individual students can be carried in this course must be a matter left to the discretion of the teaching staff, whose means of observation and power of assessing the capability of individual students can alone decide the matter. In the judgment of the Committee, it is most important that, when teachers consider that individual students are lacking in the power of proceeding successfully with their higher mathematical studies, time should not be wasted in persevering therewith. On the other hand, many students of this class under proper instruction are capable of benefiting greatly by well-considered courses of instruction in the practical applications of mathematics.

In the later terms of the college-course of study, time devoted to purely mathematical instruction should be lessened as compared with the time similarly devoted during the earlier terms; and that given to specialized instruction in engineering subjects should be increased. The most advantageous arrangement, both for students and teachers, will consist in the combination of

mathematical and engineering instruction by the professors and teachers of engineering. The teachers of pure mathematics also, in dealing with the students during their common course of study, should be well-informed as to the applications of mathematics in engineering, so that their courses of instruction may be arranged suitably, and that departments of these subjects having no bearing upon engineering may not have given to them unnecessary time or attention.

With regard to the teaching of geometrical drawing, physics, chemistry, and geology, the existing arrangements of the universities and technical colleges appear to be satisfactory and to meet all cases.

Without interference with the organization of individual colleges, it would be found in the highest degree beneficial to arrange conferences between the staffs of all the important teaching institutions; so that a uniformly high standard of qualification on the part of students, at the completion of their courses of study, may be maintained.

8. At least three to four years should be spent in practical training, inclusive of the "introductory workshop course" previously mentioned. The Committee favour a total period of four years' practical training where it can be secured: this being carried out in workshops, on works, in mines and in offices, as may be required in each case. It is highly desirable that a part of this practical training should be obtained in drawing-offices.

9. Where college training is completed before practical training is taken, the total period devoted to the latter should be three years in ordinary cases. Exceptional ability may justify a somewhat shorter period. The hours of work should be the same as if the usual course were followed: the wages paid should be somewhat higher, especially in the later years. The Committee make this general recommendation whilst recognizing that this is not the practice in mining.

10. The Committee recommend strongly efficient instruction in engineering drawing.

Instruction in testing materials and structures, and in the principles underlying metallurgical processes and other practical operations incidental to the branch of engineering in which a student proposes to specialize, should be included in the college course.

In regard to workshop practice in technical colleges, they are of opinion that boys who have spent one or two years in mechanical engineering workshops should not be instructed in workshop practice at technical colleges.

11. In connection with the grant of degrees, diplomas and certificates to engineering students, considerable importance should be attached to laboratory and experimental work performed by individual students, as well as to their progress in mathematical and scientific studies; and degrees, etc., should not be granted on the results of terminal or final examinations alone. Practical unanimity is shown in regard to this procedure by those whose opinions were obtained, and it is considered to be of great importance in assessing the professional attainment of students.

12. Facilities for, and organization of, post-graduate work by engineering students in universities and higher technical institutions should be considerably increased. This recommendation is made with the special object of encouraging qualified students to undertake researches which may prove of practical value to engineering operations and processes. The number of such students is not likely to be large at any time, but their influence on younger students should be highly beneficial, and the advantage to engineering and industry should be considerable. In many cases, the best period for post-graduate work would be that following the completion of practical training, even when that training follows the college course.

13. The Committee reaffirm the conviction expressed when they issued their inquiry, that the sympathetic assistance of employers is essential to improvement in engineering education and training.

In conclusion, the Committee desire to express their indebtedness to the Secretary (Dr. Tudsbery) and the Assistant-secretary (Mr. Henderson) for the valuable and unwearied assistance which they have rendered throughout the inquiry, and would repeat their acknowledgment of indebtedness to all those who have assisted with opinions and information.

W. H. White,
Chairman of the Committee.
J. H. T. Tudsbery,
Secretary.

April 7th, 1906.

APPENDICES.

APPENDIX I.—Schedule of Questions relating to Preparatory Education and Training of Engineers, issued by the Sub-Committee; with a Summary of the Replies received.

Question.	Summary of Replies.	Per cent.
1. What is the proper age for leaving school, having in view the fact that the boy has ahead of him a practical and theoretical training which will cover certainly four, probably five, and perhaps six years before he can become a regular assistant in any branch of engineering work?	Average age recommended—	
	Less than sixteen ...	4·5
	Sixteen ...	19·0
	Between sixteen and seventeen	14·0
	Seventeen ...	40·0
	Between seventeen and eighteen	4·5
	Eighteen ...	10·0
	Exceeding eighteen ...	8·0
2. (*a*) What is your view as to the desirability of a leaving examination for secondary schools?	(*a*) Desirable ...	90·0
	Undesirable ...	10·0
(*b*) If such an examination is possible or desirable, should it be in the hands of the school itself or of external examiners, or of both conjointly?	(*b*) School itself ...	5·0
	External examiners ...	41·0
	Both conjointly ...	54·0
(*c*) Could it, and, if so, should it, be utilized as the equivalent of a matriculation or entrance examination for the various colleges giving education to engineers?	(*c*) Yes ...	93·5
	Doubtful ...	6·5
3. English Subjects. (*a*) Is it possible to develop further than has generally been the case hitherto, the teaching of history and geography in what may be called their commercial aspects?	(*a*) Yes ...	85·5
	Not desirable ...	14·5
(*b*) Could précis-writing be included under this heading?	(*b*) In favour ...	84·0
	Doubtful or not in favour ...	16·0
(*c*) Can anything be done to give extended instruction and exercise in essay writing?	(*c*) In favour ...	88·0
	Doubtful or not in favour ...	12·0
4. Languages. (*a*) How far is it desirable that boys definitely intended for the engineering profession should continue the study of the classical languages, or of either of them, until the time when they leave school?	(*a*) In favour ...	47
	Recommend discontinuance at least two years earlier ...	41
	Recommend omission of classics altogether ...	12
(*b*) If it is thought that the study of these subjects ought to be continued to the end, what amount of time should be spent upon them during the last two years?	(*b*) About 5 or 6 hours a week ...	77
	About 10 hours a week ...	23
	The replies to (*a*) and (*b*) refer, in the majority of cases, to Latin alone, the general opinion being that Greek may be either omitted entirely or discontinued at an earlier stage.	
(*c*) To what extent can modern languages—especially French and German—be taught colloquially or in such fashion as to make them really useful, without the expenditure of unnecessary time on theoretical grammatical exercises or in the study of classical comedies?	(*c*) Approve of this method ...	77
	Doubtful or not in favour ...	23
	In many cases residence abroad is recommended as the only means of acquiring a real colloquial knowledge of modern languages.	

APPENDIX I.—*Continued.*

QUESTION.	SUMMARY OF REPLIES.	Per cent.
5. Mathematics. (*a*) Can general mathematical teaching be given to boys who intend to become engineers in such a way as to help them later on in the practical use of mathematics—such a method of teaching naturally differing much from the method which would be used if mathematics were to be merely an intellectual exercise, not actually employed later on in real life, nor even used for the sake of passing an examination?	(*a*) In favour	85
	Not in favour	15
(It has to be remembered that in the great majority of cases the boys whose natural bent is towards engineering find the geometrical side of mathematics fairly easy, but have difficulties with its analytical side. It is considered desirable also that boys leaving school for engineering training should have more than the mere minimum represented by four books of Euclid, etc. They ought certainly to know something about logarithms and the elements of trigonometry, and also about similar figures. It is thought that ample opportunity for such teaching could be found by the omission of the matters mentioned in (*5*) below.)		
(*b*) Is it desirable that the teaching of mathematics at school should be arranged with a view to attain all or any of the following objects?—	(*b*)	
1. The practical use of arithmetic with the special object of obtaining correct results independently of the mere study of arithmetical methods.	*1.* Yes	81
	No	19
2. The encouragement of the use of contracted methods.	*2.* Yes	91
	No	9
3. The encouragement of exercises in mental arithmetic.	*3.* Yes	94
	No	6
4. The teaching, at this stage, of what Prof. Perry has called "practical mathematics," of the use of logarithms, of elementary trigonometry (limited, for example, to right-angled triangles), of the general ideas of projective geometry, including points and lines at infinity, and the use of the slide-rule.	*4.* Yes	85
	No	10
	Omit slide-rule	5
5. The elimination from instruction in mathematics of such matters as cube-root extraction and elaborate algebraic equations, which are purely intellectual gymnastics without any direct usefulness.	*5.* Yes	90
	No	10
6. Science. (*a*) Is it better that boys should be made superficially familiar with the general language and ideas of elementary physics and chemistry, or that they should be carried somewhat further in one particular section of such work?	(*a*) Recommend former	67
	,, latter	23
	,, both conjointly...	10

APPENDIX I.—*Continued.*

QUESTION.	SUMMARY OF REPLIES.	Per cent.
6. Science.—*Continued.*		
(*b*) Would it be advisable rather to encourage the general study of what used to be known as "natural philosophy" as a subject of general mental training as well as of practical interest?	(*b*) Yes	78
(It has been a matter of common complaint among engineering professors that in many cases the mechanical ideas imbibed by schoolboys have done more harm than good in their subsequent study of the subject. If, however, it were possible to give schoolboys a thorough grounding in the elements of mechanics it would, of course, be useful.)	No	22
(*c*) In view of the results hitherto obtained, would it be well to omit theoretical mechanics altogether from school teaching.	(*c*) Yes	77
	No	23
7. Practical Work. (*a*) How far has it been found desirable that schoolboys should have, as a school exercise, practice in ordinary handicraft work, such as carpentry or turning?	(*a*) Undesirable as a school exercise	44
	Desirable	38
	Desirable in some cases, or to a limited extent	18
	In many cases it is recommended that the boys should be encouraged to take up handicraft work, as a recreation, out of school hours.	
(*b*) To what extent has it been found better and more useful, to make the "practical" work really into laboratory exercises or experiments, whether physical, chemical or mechanical?	(*b*) Consider it desirable and practicable	38
	Consider it desirable	42
	Do not recommend this method	20
8. Drawing. What are your views as to the following schemes of instruction in drawing to be taught in school to boys who are going afterwards into engineering?		
(*a*) The ordinary teaching of geometrical drawing with orthographic projection, including especially curve drawing, both by co-ordinates and by purely projective methods.	(*a*) Desirable	92
	Undesirable	8
(*b*) Free-hand drawing from ordinary drawing-class models or from solids representing simple details of an engineering character.	(*b*) Desirable	96
	Undesirable	4
(*c*) The drawing, in orthographic projection, of objects from actual measurement, a subject which has been called practical mensuration.	(*c*) Desirable	83
	Undesirable	17
9. Surveying. Is it desirable, and, if so, is it possible, to include anything like instruction in simple chain surveying, without optical instruments, for boys during their school period?	Undesirable	53
	Possible and desirable	31
	Desirable	16

APPENDIX II.—Schedule of Opinions and Questions relating to Training in Offices, Workshops, Factories or on Works; and in Technical Colleges and Universities; with a Summary of the Replies received.

Comments and replies are invited upon the following opinions and questions. In making them it is requested that answers be given with special reference to boys of average ability, who are destined for the engineering profession and who have sufficient means to go through a full course of training. Alternative suggestions will be welcomed and will receive full consideration.

Opinion or Question.	Summary of Replies.	Per cent.
1. The Committee are of opinion that the age for leaving school be about 17 years.	Agree	70
	Prefer sixteen	17
	Prefer eighteen	7
	Prefer fifteen	4
	Other replies	2
2. (*a*) The Committee are of opinion that it is desirable that the course of training for all branches of engineering should include at least one year's training in mechanical engineering workshops, where, ordinarily, information would be gained of the practical applications of electricity. (This is referred to hereafter as the "introductory workshop course.")	(*a*) Agree	72
	One year too short	21
	Do not agree	4
	Other replies	3
(*b*) The Committee think that this introductory workshop course should be taken at an early period—either previously to the commencement of college training, or after that portion of the college training which is common to all branches of engineering (*see* 6 below) has been completed.	(*b*) Agree	33
	Before college	47
	After common portion... ...	10
	Complete college first... ...	5
	Alternating with college ...	3
	Other replies	2
3. The Committee are of opinion that during this (and any subsequent) course of training in workshops, boys should keep the regular working hours, including early morning attendance, and should be treated like ordinary apprentices, and be paid wages.	Agree	79
	Do not agree entirely... ...	8
	Shorter hours if attending evening classes	7
	Should not be paid wages ...	5
	Other replies	1
4. Is it desirable, having regard to the age and physical development of the boys— (*a*) To require them to attend classes for evening study during this introductory workshop course; or, (*b*) That this period should be devoted entirely to practical work—ordinary educational work being meanwhile suspended?	(*a*) and (*b*)	
	Former preferable	55
	Latter preferable	35
	Former, with shorter working hours	3
	Depends on individuals ...	2
	Other replies	5
5. Assuming such an introductory workshop course to be approved for all boys, is it recommended— (*a*) That it should be followed by a period of study in a technical college or university before specialization in particular branches of engineering is undertaken; or, (*b*) Is it considered preferable that this workshop course should be at once followed by a period of practical training in the branch of engineering for which the boy is intended; or,	(*a*) and (*b*)	
	Former preferable	64
	Latter preferable	31
	Other replies	5

APPENDIX II.—*Continued.*

OPINION OR QUESTION. / **SUMMARY OF REPLIES.**

5.—*Continued.*

(*c*) Is it deemed desirable that the period of college study should be arranged so as to alternate with the workshop or other practical training —and, if so, in what manner?

(*c*)	Per cent.
Desirable	63
Undesirable	29
Difficult to arrange	5
Desirable in some cases	1
Other replies	2

Of those who consider the course indicated in (*c*) desirable, 42 per cent. recommend attendance at college during the winter 6 months, and at the workshop during the summer 6 months, in each year.

6. The Committee are of opinion that the earlier course of college study should be arranged so as to be common to all branches of engineering. This being assumed—

(*a*) How long a period should be assigned to such common course of study?

(*b*) What is a reasonable total period of college study for a boy of average ability?

	(*a*) Per cent.	(*b*) Per cent.
One session	38	2
One or two sessions	6	.
Two sessions	42	15
Two or three sessions	2	7
Three sessions	5	51
Three or four sessions	1	9
Four sessions	2	11
Four or five sessions	...	1
Five sessions	...	1
Other replies	4	3

7. To what extent should college study be carried, in

(*a*) Mathematics?
(*b*) Geometrical drawing?
(*c*) Physics?
(*d*) Chemistry?
(*e*) Geology?

	(*a*) Per cent.	(*b*) Per cent.	(*c*) Per cent.	(*d*) Per cent.	(*e*) Per cent.
Recommend standards comparable with that of B.Sc. (in engineering) of London University	54	10	11	8	7
The more the better	23	23	27	18	15
Advanced instruction	13	32	28	23	12
Elementary instruction	...	17	18	18	34
Should be taught with regard to its application in engineering	...	9	...	2	5
Include laboratory	...	...	6	20	...
Should be optional	...	...	...	...	15
Other replies	10	9	10	11	12

8. Apart from the introductory workshop course, what is considered to be a reasonable total period of practical training on works, in factories, workshops, mines, etc., when the age of specialization is reached?

	Per cent.
One year	4
One to two years	3
Two years	21
Two to three years	11
Three years	31
Three to four years	5
Four years	8
Four to five years	1
Five years	4
Over five years	3
Other replies	9

APPENDIX II.—*Continued.*

OPINION OR QUESTION.	COMMENT OR ANSWER.

9. In cases where boys complete their college training before beginning their practical training, what is thought best—considering that they must now be about 21 years of age—

(*a*) In regard to the introductory workshop course?

(*b*) In regard to the period required for specialization in particular branches of engineering?

(*c*) In regard to hours of work and payment of wages in workshops, drawing-offices, mines, works, etc., during such period of specialization?

Would your suggestions in the foregoing respects differ, and, if so, to what extent in cases where practical training preceded or alternated with the college course?

	(*a*) Per cent.	(*b*) Per cent.	(*c*) Per cent.
Same as if taken earlier	33	33	76
May be shortened ...	4	1	...
Should be omitted ...	26	...	...
One year	19	5	..
Eighteen months ...	2	3	...
Two years	5	17	...
Two to three years ...	...	5	...
Three years	3	19	...
Four years	...	4	..
Until proficient	...	2	...
Wages should be higher...	...	...	10
Other replies	8	11	14

With only a few exceptions, the replies to this question are all in the negative.

Entire disapproval of the course referred to in (9) is expressed in more than 50 per cent. of the replies.

10. Is it desirable to provide, and, if so, on what scale, in technical colleges, appliances and equipment for instructing students in—

(*a*) Engineering drawing?

(*b*) Workshop practice?

(*c*) Testing materials or structures?

(*d*) Metallurgical processes?

(*e*) Other practical operations incidental to engineering works?

	(*a*) Per cent.	(*b*) Per cent.	(*c*) Per cent.	(*d*) Per cent.	(*e*) Per cent.
Yes; in general, scale to be limited only by the funds at disposal	80	48	86	69	71
No	6	36	2	10	13
Doubtful ...	...	...	...	6	2
On small scale only	...	9	...	9	.
Moderate equipment	...	...	8	...	...
In some colleges	...	...	...	2	...
To teach principles	6	3	...	...	7
To illustrate lectures	2	2	1	1	2
Include principles of design ...	3	...	...	...	...
Other replies ...	3	2	3	3	...

11. The Committee are of opinion that it is desirable, in connection with the grant of degrees, diplomas and certificates to engineering students, that considerable importance should be attached to laboratory and experimental work performed by individual students, as well as to their progress in mathematical and scientific studies, rather than that degrees, etc., should be granted on the results of terminal or final examinations alone.

	Per cent.
Agree	91
Not too much importance ...	2
Already being done	2
Reports from works also desirable	2
Other replies	3

12. The Committee are of opinion that facilities for, and organization of, post-graduate work by engineering students in higher technical institutions should be considerably increased.

Agree	83
Do not agree...	5
Scholarships required	2
By specially qualified students only	3
Difficulty to attract the best men	1
Other replies	6

APPENDIX II.—*Continued.*

OPINION OR QUESTION.	COMMENT OR ANSWER.	Per cent.
13. The Committee are of opinion that the improvement of engineering education depends greatly on the attitude of employers towards the suggestions foreshadowed in this memorandum; and the Committee would especially urge upon employers the importance of extending facilities to engineering students for the prosecution of post-graduate work.	Agree	74
	Do not agree	4
	Employers willing to grant facilities	7
	Students must show themselves capable	4
	Difficulties in the way	3
	Other replies	8

MANCHESTER GEOLOGICAL AND MINING SOCIETY.

GENERAL MEETING,
HELD AT THE ROOMS OF THE SOCIETY, QUEEN'S CHAMBERS,
5, JOHN DALTON STREET, MANCHESTER,
JANUARY 9TH, 1906.

MR. HENRY BRAMALL, PRESIDENT, IN THE CHAIR.

The following gentlemen were elected, having been previously nominated: —

MEMBERS—

CAPTAIN HENRY VAUGHAN HART-DAVIS, Bridgewater Collieries, Walkden, near Manchester.

MR. WILLIAM YOUNG, Hindley Field and Victoria Collieries, Bickershaw, Wigan.

CONFERENCE OF DELEGATES OF CORRESPONDING SOCIETIES OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, LONDON, 1905.

Mr. WILLIAM WATTS, Delegate of the Society to the meeting of the Corresponding Societies of the British Association for the Advancement of Science, read his report, from which the following abstract has been made:

Agreeably with the request of the Council of the Manchester Geological and Mining Society, I attended the meetings of the Delegates of the Corresponding Societies of the British Association for the Advancement of Science, held at Burlington House, London, on October 30th and 31st, 1905.

The number of affiliated societies is 70, representing 25,000 members spread over the United Kingdom. The meeting was presided over each day by Dr. A. Smith Woodward, and was a complete success, both as regards the number of members present and the interest taken in the proceedings.

A paper was read on "The Law of Copyright as affecting the Proceedings of Scientific Societies": it evoked an interesting discussion as to the difficulty involved in legislating on the subject. Copyrights are of two kinds, namely, private and public. A person writing a book, play or music, has no difficulty in protecting it, but it is difficult to protect a lecture given in public *viva voce*, although it calls forth the knowledge and genius of the lecturer just as

much as a book or play written in the quietude of home. The lecturer, however, can protect himself by having his lecture printed before delivery, but this is not always convenient, and if in the inspiration of a moment he makes valuable *viva voce* remarks, which draw upon the experience of a lifetime, they may be appropriated by others to their own advantage.

In the opinion of your delegate, lectures should be made copyright property, and not publicly used unless the author desired publication; but their usefulness in spreading knowledge would be less, and the classes for whom the information was intended would be the sufferers. Special legislation for the protection of lectures, speeches, poetry and songs is difficult to secure; but it seems only fair that literary and scientific matter should not be pirated by writers and critics who have a faint knowledge of the subjects criticized, unless permission to submit the matter is previously obtained. Criticism is most valuable when it comes from a writer who possesses superior knowledge, but not otherwise; and authors should be protected from the unfair comments of ignorant scribblers.

Your delegate has endeavoured to bring before his Society the main points of interest introduced at the Conference, he fully appreciates the honour conferred by your Council in such an appointment, and trusts that the Manchester Geological and Mining Society will do what it can, through its individual members, to help the British Association in its scientific work.

The PRESIDENT (Mr. H. Bramall) moved a vote of thanks to Mr. Watts for his report, and the interesting information that he had placed before the members.

Mr. JOHN GERRARD (H.M. Inspector of Mines) seconded the motion, which was carried unanimously.

Mr. JAMES ASHWORTH read the following paper on "The Elba and Clydach Vale Colliery Explosions":—

THE ELBA AND CLYDACH VALE COLLIERY EXPLOSIONS.

By JAMES ASHWORTH.

Although the evidence given at the inquests on the miners killed by the recent explosions at these collieries* did not disclose the precise means by which the explosive mixture of fire-damp and dust and air became ignited, yet it did point out, to the satisfaction of the coroners and their juries, and of H.M. inspectors of mines, the locale of the initiation of both explosions.

In the enquiry into the explosion at the Elba colliery, the verdict of the jury was as follows:—(1) That the cause of death was by an explosion; (2) that the nature of the explosion was fire-damp; (3) that it occurred in No. 4; and (4), in our opinion, the cause was probably a naked light.

In the enquiry into the explosion at the Clydach Vale collieries, the verdict of the jury was as follows:—(1) On the evidence submitted to us we are unanimously of the opinion that the explosion occurred in No. 6 cross-cut of the No. 5 district. (2) We are also of opinion that the explosion occurred in consequence of something happening to David Enoch's lamp; and (3) that no blame can be attached to anyone for the explosion. The jury added the following rider: We recommend the management to spare no effort to enforce Rule 179. [This rule has reference to the giving out to each man of the same safety-lamp, day after day, so far as is practicable.]

The safety-lamps used at both collieries were of the same types, namely, the bonneted Clanny, and the bonneted Jack Davy lamp (generally known as the Cambrian fireman's Davy lamp), and they were of first-class construction.

At the Elba colliery, no open light was found, and the suggestion that the explosion was caused by an open light was

* Elba colliery on January 21st, 1905; and Clydach Vale colliery on March 10th, 1905.

based on matches being found in a waistcoat hanging in the level near No. 4 heading, and a pipe found in the pocket of a miner's coat, which was also hanging up between Nos. 5 and 6 heading, on the lower side of the level. Two matches and an empty cigarette-box were also found in a waistcoat belonging to one of the men injured by the explosion. All the lamps were found locked, and in apparently good order when recovered.

Mr. J. T. Robson, H.M. inspector of mines, in his evidence is reported to have said that there was gas in No. 5 heading, top hole, that the explosion happened inside of No. 4 heading, that the whole of the gas in No. 3 heading where there was a big fall, was not exploded at the time; that without going to the length of saying that it was utterly impossible that the explosion could have happened with a lamp in apparently good condition, he thought it most highly improbable, and at any rate in this case it did not happen. The lamps were all right. It was highly improbable, for the reason that "invariably these lamps go out as soon as ever they come into contact with an explosive mixture."

At the Clydach Vale enquiry, Mr. F. A. Gray, H.M. inspector of mines, is reported to have said that he approved of the firemen using the Davy lamp and the Clanny lamp on their rounds; that when he saw David Enoch's body at the place where it was found, he was satisfied that the explosion occurred in the No. 5 district; that this was also the conclusion of Messrs. L. Llewelyn, W. W. Hood, D. Hannah and T. Griffiths, and of his assistants, Messrs. J. D. Lewis and F. J. Trump. He thought that the explosion originated in the ignition of gas, and was carried from district to district by coal-dust; and, contrary to the majority of explosions, this one travelled through the return-airway with a great deal of force. The coroner, in summing up, said that everybody was in absolute agreement that the starting point of the explosion was in Daniel Price's district, and that there was only one human being there at the time; and it occurred to him that David Enoch was "doing something to clear the gas when something happened which started the explosion."

Judging from these reports, it appears certain that in the Clydach Vale colliery, as well as at the Elba colliery, a man was

doing "something" with accumulated fire-damp, probably with the idea of removing it. It is not the least likely that either man would be playing with matches under such conditions, and therefore the only source of flame would be encased in a bonneted Clanny lamp (Fig. 12) at the Elba colliery, and in either a bonneted Clanny or a bonneted fireman's Davy lamp (Fig. 13) at Clydach Vale colliery.

Evidence was given that all these lamps were in good condition when delivered to the men, and that they were not found unlocked. What then initiated these explosions? The first natural conclusion must be that they were caused by the failure of safety-lamps of approved construction to justify their designation of "safety-lamps." To prove circumstantially that the name "safety" is only an alias, when applied to these two patterns of miners' lamps, we need to turn to the finger-prints left behind in the present instances, and compare them with those so distinctly recorded by previous disasters. Thus the admittedly dangerous conditions at the Elba and Clydach Vale collieries were caused by admixtures of air, fire-damp and coal-dust; and as no evidence was given as to the velocity of the ventilating current, it may be assumed that it was much the same in both cases.

FIG. 12.—BONNETED CLANNY SAFETY-LAMP.

For the sake of comparison, the explosions at Allerton Main colliery and Shakerley colliery, may be referred to, as in both cases the only means of ignition was that of the flame within a safety-lamp, and in the latter case the lamp (Fig. 1, Plate XI.) was practically in a quiescent atmosphere. The bonneted Clanny safety-lamps in use at both of these collieries were experimentally tested after the disasters in various velocities of, and mixtures of, fire-damp and air, and in neither case did the lamps fail; but it is to be noted that one factor was omitted from the tests, namely, coal-dust. It is, therefore, clear that the neglect of this factor lessened the value of the tests, and did not afford any proof that these lamps were safe in a dusty mine.

So long ago as 1852, Mr. James Darlington, a mining engineer when giving evidence before a Governmental Commission, said that many explosions had occurred in collieries which he could only attribute to ignited coal-dust flying off a Davy lamp in which gas was burning.*

In 1879, the writer, when experimenting with Davy lamps in currents of air mixed with fire-damp, found that a mixture of 4½ per cent. of gas in a velocity of 370 feet per minute would burn for a long time within the gauze without the flame passing out of it; but if, in addition, the air were carrying coal-dust in suspension, just as much as it would pick up naturally from the floor, the lamps would pass the flame in 10 seconds and cause an explosion.†

FIG. 13—BONNETED FIREMAN'S DAVY SAFETY-LAMP.

Mr. C. E. Rhodes also made some safety-lamp experiments with coal-dust, and his opinion was, that explosions might be caused much more easily, and at a lower velocity when coal-dust was a factor than when it was absent.‡

The writer does not know of any other experiments that have been made on safety-lamps with coal-dust in suspension in an air-current charged with a low percentage of fire-damp, and as the Royal Commission, appointed to report on Explosions

* *Report from the Select Committee on Coal-mines*, 1852 [509], page 108; and *Trans. N.E. Inst.*, second edition, 1860, vol. i., page 309.

† "Improved Safety-lamps of the Davy and Mueseler Types," by Mr. James Ashworth, *Trans. N.E. Inst.*, 1880, vol. xxix., page 148.

‡ Letter to the author of April, 1905.

from Coal-dust in Mines, did not touch on this danger the subject has remained almost entirely neglected.

There are, however, other points in the construction and use of safety-lamps which have received very close attention, and although the results of the experiments have been published, they are still very imperfectly understood or observed.

The honour of being the pioneer-investigator of the safety of the details of a safety-lamp, undoubtedly belongs to the noted French mining engineer, Mr. J. B. Marsaut,* and in this he was followed by the Prussian and Saxon Commissions. Each of them made tests on the size of mesh, and of the wire, used in the gauze of safety-lamps, and although they did not all adopt the Davy size of mesh, yet they did agree that a mesh of 784 apertures to the square inch, and made of wire $\frac{1}{60}$ inch in diameter was a firm and reliable covering, and that a Davy gauze, 1½ inches in diameter and about 4 inches high, was a safe and satisfactory protection to the lamp-flame, when exposed to quiescent mixtures of air and fire-damp, or to explosive currents of low velocity.

All experimenters have also agreed, that every increase in the diameter of a gauze above 1½ inches reduces its power of resistance. When glass surrounds the wick-flame, without the interposition of a gauze-covering, practically all are agreed that the best form of gauze to surmount the glass is that of a truncated cone with the smallest diameter at the top (Fig. 2, Plate XI.), that the most dangerous form is the reverse (Fig. 3, Plate XI.), with the largest diameter at the top, and that a gauze, with the addition of a metal-disc with a hole, *a*, in it of the same size as the top of the gauze (Fig. 4, Plate XI.), is equally dangerous.

In another series of experiments, Mr. J. B. Marsaut assumed that the cylindrical glass of a Clanny lamp produced an effect similar to that of a cannon when an explosion occurred within the lamp, and he proceeded to cover the base of the gauze with bands of paper of various widths, thus discovering that the more

* "Étude sur la Lampe de Sûreté des Mineurs," by Mr. J. B. Marsaut, *Bulletin de la Société de l'Industrie Minérale*, 1883, vol. xii., page 321. "Miners' Safety-lamps: an Investigation," by Mr. J. B. Marsaut, *Transactions of the Midland Counties Institution of Engineers*, 1884, vol. xii., page 179. "The Marsaut Lamp," by Mr. M. Walton Brown, *Trans. N. E. Inst.*, 1885, vol. xxxiv., page 161.

space he covered the more he reduced its safety. The soundness of this reasoning was confirmed by the Prussian Fire-damp Commissioners who carried it a point further, namely:—That any covering-up or obstruction, *a*, of the upper part of the gauze (Fig. 5, Plate XI.) also added to the possibility of the flame of an explosion passing from within the lamp to the surrounding atmosphere. They further proved that the doubling of the top of the gauze by a cap of gauze, *a* (Fig. 6, Plate XI.) or thin metal, *a* (Fig. 5, Plate XI.), also lessened the safety of the gauze-part. These experiments confirm Mr. Marsaut's results, for instance, where by placing a disc of gauze, *a*, in a Davy lamp a short distance below the top (Fig. 7, Plate XI.), he found that gas was easily ignited in a quiescent atmosphere in the annular space, *b*, thus formed. Mr. Marsaut also proved that if a second gauze, *a*, were placed round a Davy gauze, *b* (Fig. 8, Plate XI.), and in close contact with it near the top, thus creating an annular space round the gauze, the gas within this space was easily ignited by an explosion within the first gauze. These experiments demonstrated that the custom of placing a smoke-cap of gauze on the top of Davy and Clanny lamp-gauzes seriously reduced their safety; it likewise shewed that the safety of a gauze which from any cause had become smoked up or closed with dirt, was thereby seriously reduced; further they demonstrated that a single gauze was safer without a smoke-cap than with one; and that when using double gauzes, as in the Marsaut lamp, there must be a clear annular space between the two gauzes, *a* and *b*, and that the thickening caused by the joining of the gauze-disc, *c*, with the sides as in some makes of gauze (Fig. 9, Plate XI.), should not project far enough to touch the inside of the outer gauze, nor yet project upwards so as to come into contact with the top of the outer gauze. A glass-lamp, with one or more superposed gauzes, was more liable to pass the flame of an explosion within the lamp to the outer atmosphere, if a small flame was being used, and still more so if it was canted on one side.

Applying these deductions of Mr. Marsaut and the Prussian Fire-damp Commissioners, it is reasonable to assume, until the contrary is proved, that the Evan Thomas No. 7 safety-lamp (Fig. 10, Plate XI.), recommended by the Royal Commission

on Accidents in Mines as having "given upon the whole the best results,"* would not safely withstand a series of tests in quiescent explosive mixtures of air and fire-damp; that neither the Davy nor the ordinary Clanny lamps ought to be fitted with smoke-gauzes; that the bonneted Jack Davy lamp (Fig. 13), so largely used for making examinations for fire-damp, is seriously reduced in safety when testing for gas if the cylindrical glass is pushed up to the top of the lamp, thus covering the upper part of the gauze; and if, in addition, it is both sooty and dirty and used in an inclined position, it becomes actually dangerous.

The cooling effect on a wire-gauze by an explosive current of low velocity is less than that of a high one, and consequently a fire-damp flame may pass through a gauze more readily in a low velocity than in a high one.

When fire-damp fills a lamp from the top it sets up more dangerous conditions than when it enters from below or horizontally, and many bonneted safety-lamps are so imperfectly shielded from descending or vertical currents, that it is possible for them to become filled with fire-damp, and to have the wick-flame crushed down and thus bring about an especially dangerous condition, as noticed by the Belgian Fire-damp Commission and Mr. Marsaut (Fig. 11, Plate XI.).†

Dust mixed with fire-damp, and forced on to a lamp by a fall of roof or otherwise, may become incandescent in the burning gas within the lamp, and passing through the gauze in this condition may ignite the surrounding atmosphere without the gauze becoming more than red hot.

In ordinary safety-lamps, the gas-and-air mixture continues to burn inside the gauze after the wick-flame is extinguished, and, therefore, they ought to have double gauzes as in the Marsaut lamp.

Applying the foregoing experimental and positive facts to the elucidation of the Elba and Clydach Vale explosions, it appeared in the opinion of the writer, reasonable to conclude that:—(1) They were caused by the failure of perfectly good safety-lamps of approved construction; (2) the failures were

* *Final Report of H.M. Commissioners appointed to inquire into Accidents in Mines*, 1886, page 118.

† An explosive mixture, ignited by an electric spark at the point, *a*, ordinarily occupied by the flame, passes the gauze at every ignition.

due to the lamps becoming filled from the top with fire-damp, only slightly diluted with air, and accompanied by some coal-dust; (3) either explosion may have originated whilst an ordinary test for fire-damp was being made: (4) as other explosions had occurred in like manner, but had always been attributed to the ignition of gas after a fall of roof had first smashed a lamp and uncovered the wick-flame, the time had arrived when an enquiry should be made as to the dangerous influence of coal-dust on the stability of all types of bonneted safety-lamps; (5) no type or pattern of safety-lamp, which had not first been submitted to, and approved by the Home Office authorities, should be allowed in a coal-mine where safety-lamps were required: and lastly, (6) the recommendation of the Royal Commission on Accidents in Mines should be enforced, namely, (*a*) "it is most important that the merits of new inventions [relating to safety-lamps] should be properly ascertained"; (*b*) "it would be desirable for the Government to maintain an apparatus [for testing], such as we have used in our experiments, and to appoint some person to test and report to the Secretary of State on any [safety-]lamps which may be submitted to him" [for use in mines];* (*c*) "only those lamps should be used which are authorized from time to time by the Secretary of State"; and (*d*) "the use of ordinary Davy and Clanny lamps . . . . should be prohibited, unless they are enclosed in cases capable of effectually preventing the

Fig. 14.—Large Bonneted Clanny Safety-lamp.

* *Final Report of H.M. Commissioners appointed to inquire into Accidents in Mines*, 1886, page 88.

gauze from being exposed to the full force of the current of air."*

It may be assumed, without any fear of exaggeration, that there is no legal limit to the dimensions of the gauze part of a safety-lamp, nor to that of the glass part, nor to the size or form of the bonnet, nor is it really necessary to prove that any new or old construction of safety-lamp is really safe before being taken into the workings of a colliery; and, therefore, so long as a safety-lamp is so constructed as to be carried against the velocity of air-current "ordinarily" prevailing in that part of the mine in which the lamps are for the time being in use, even though such current should be inflammable, the law is fully complied with.

Fig. 14 is the biggest lamp of the bonneted Clanny type ever seen by the writer, and its failure whilst in sound condition caused an explosion, in October, 1904, at the Birmingham gas-works, by which two men were killed and immense damage done to the purifying and other buildings. This lamp is a good illustration of the very wide difference there is between the dimensions adopted by Sir Humphrey Davy and those used in some cases at the present day, as the following approximate table shows:—

Description of Safety-lamp.	Contents of the Glass or Cannon Part. Cubic Inches	Contents of the Gauze Part. Cubic Inches.	Total Contents exposed to an Internal Explosion. Cubic Inches.
Evan-Thomas, No. 7 (Fig. 10, Plate XI.)	10·45	5·50	15·95
Bonneted Clanny (Fig. 12)	7·80	10·60	18·40
Bonneted Fireman's Davy (Fig. 13)	0·00	8·00	8·00
Large Bonneted Clanny (Fig. 14)	96·00	57·00	153·00
Scotch Gauze	0·00	86·50	86·50

The large bonneted Clanny lamp (Fig. 14) also differs from the bonneted Clanny lamp (Fig. 12), in having a supplementary air-supply to the wick-flame through two tubes, which are seen projecting above the oil-reservoir. These tubes are protected by a fixed disc of gauze placed between them and the air-admission holes in the side of the base of the lamp.

In conclusion, it is very important to note that a safety-lamp may be safe when carried against the current ordinarily prevailing in a certain part of a mine, even when it is inflammable,

* *Final Report of H.M. Commissioners appointed to inquire into Accidents in Mines*, 1886, page 118.

and yet may not be able to withstand the rush of air, gas and dust caused by a fall of roof, such as is of common occurrence in collieries.

The President (Mr. H. Bramall) proposed a vote of thanks to Mr. Ashworth for his paper.

Mr. W. Saint seconded the resolution, which was unanimously approved.

Mr. John Gerrard (H.M. Inspector of Mines) said that he would first speak of that portion of the paper with which he entirely agreed, and which very strongly commended itself to him. He thought that one of the most important points was touched upon at the close of the paper, when Mr. Ashworth remarked upon the extraordinary fact that almost any lamp could be taken into a mine, however dangerous; this statement seemed strange at first sight. There was nothing really to fix or determine what was a safety-lamp; and that fact led him to express the hope that soon there would be an authorized establishment for the testing of lamps, to prove whether they were safe or dangerous, and not to wait until they had been tested in a mine by loss of life. It was exceedingly interesting to him (Mr. Gerrard) when visiting Belgium to see the admirable testing-station connected with the Belgian Government, under the supervision of two inspectors of mines, where a series of experiments were made with a number of lamps. If there were in this country some similar lamp-testing station, he was sure that it would be of very great advantage.

Fig. 15.—Safety-lamp Gauzes. A: Shakerley Lamp, B: Single Gauze and Cap.

The next point of agreement that he had with the writer of the

paper was associated with the introduction of lamps into Lancashire. He thought that up to recently there were a very large number of Marsaut lamps in use with proper double gauzes, and it had given him (Mr. Gerrard) some anxiety to notice that recently lamps were being introduced, into the collieries of Lancashire, with a single gauze, and a cap on the top similar to the cap (B, Fig. 15), which had been so strongly condemned by Mr. Ashworth. It was not only the single gauze with the small cap at the top to which he objected; the type of the gauze was not right. Fig. 16 was the lamp which unquestionably caused the Shakerley explosion; and, although it stood condemned as a type of lamp which could not be depended upon, it was this kind of lamp which was being extensively used in some of our most fiery mines. A (Fig. 15) is the gauze of the lamp shewn in Fig. 16.

Fig. 16.—Bonneted Clanny Safety-lamp: Shakerley Colliery.

There were three points which should be very carefully considered in reference to these lamps:—(1) The fact that they had a single gauze. (2) They were of large internal capacity as compared with the old form of Clanny lamp, which had been so much criticized and had caused many explosions. He had himself investigated explosions that were held to be due to the use of that form of lamp. The diameter of the Shakerley lamp-gauze was $1\frac{1}{2}$ inches and the height $3\frac{3}{4}$ inches, and the diameter of the new lamp-gauze was 2 inches and the height 4 inches. (3) The cap was, probably, intended to be an additional

safeguard, but, if he were right in his estimation of Mr. Ashworth's remarks, it stood condemned.

Referring to that part of the paper with which he (Mr. Gerrard) did not agree, in connection with his colleague, Mr. F. A. Gray, H.M. inspector of mines, who had made a most able report upon the Clydach Vale colliery explosion; he (Mr. Gerrard) said that Mr. Ashworth had dealt with the cause of this explosion, and there was some discrepancy between Mr. Ashworth's statements and the statements embodied in Mr. Gray's official report, and he submitted that Mr. Ashworth had not done Mr. Gray full justice. Mr. Gray thought that the cause of the explosion was the lamp used by David Enoch, and he condemned its use.

He (Mr. Gerrard) was glad that this question of safety-lamps had been raised, and he hoped that it would be seriously considered by the mining world. To his mind, the Shakerley lamp was better in form than the modern type, which was being largely used. After the Shakerley colliery explosion, this lamp (Fig. 16) was experimented upon to see whether, at a low velocity, flame would pass the gauze. It was true that they did not succeed in passing flame at a low velocity, but the lamp got into such a red-hot condition, that one could readily understand that a little disturbance of the air, and the raising of some dust, would lead to a disaster. The specific point upon which he desired Mr. Ashworth's opinion was as to the form of the gauze in the lamp put before the meeting. Another statement of Mr. Ashworth's wanted explanation, "the cooling effect on a wire-gauze by an explosive current of low velocity is less than that of a high one, and consequently a fire-damp flame may pass through a gauze more readily in a low velocity than in a high one."* If that statement implied that it is safer to jerk a lamp quickly out of gas, he (Mr. Gerrard) entirely dissented; the opposite had been proved again and again. The Special Rules required a lamp to be withdrawn slowly from gas.

Mr. Geo. H. Winstanley remarked that many modern so-called safety-lamps appeared to be made without knowledge or due regard of essential scientific principles, and many firms made lamps like the one exhibited by Mr. Gerrard. In the case of the English pattern of the Mueseler lamp, this was particu-

* *Trans. Inst. M. E.*, 1906, vol. xxx., page 515.

larly evident; and, whilst in the original Belgian lamp the dimensions of the various parts were carefully laid down by the Government, the English copy, used in at least one extensive Lancashire colliery, was a Mueseler in name only, the makers having entirely lost sight of its essential features.

Mr. Sydney A. Smith (Honorary Secretary) understood that Mr. Ashworth claimed that this particular lamp, in an atmosphere with a small percentage of gas, without dust, would not pass the flame through the gauze, but that under certain conditions, when dust was floating about, the particles of dust might become incandescent and then pass thraugh the gauze and ignite the explosive atmosphere at the outer side of the gauze. In other words, the incandescent particles of dust, passing through the gauze, would ignite the explosive atmosphere of a small percentage of gas and dust on the other side of the gauze. In his own view, it was hardly possible for those particles of incandescent dust to pass through the gauze at such a temperature as to fire the mixture outside, unless the gauze was at a temperature such that it would pass the flame entirely independent of the particles of incandescent dust, or itself fire the explosive mixture of air, gas and coal-dust.

The President (Mr. Henry Bramall) said that he had listened to Mr. Ashworth's paper with great interest, but when he heard the description of the finding of matches, pipes and cigarettes in fiery mines, he wondered whether the discipline was as strict as it might have been, apart from the question of the kind of lamp in use. The recommendation that each miner should have his own lamp struck him, too, as a little curious, as it had always been his own practice, and he thought that it was the general practice of other managers, in Lancashire at all events, for every miner to have his own lamp and to be held responsible for it. He considered this to be very necessary. Mr. Ashworth had done good service in recalling attention to the experiments of Mr. J. B. Marsaut on the forms of safety-lamp gauzes, as these experiments were not so familiarly known as they ought to be. The suggestion was ingenious that coal-dust or other dust was fine enough to be carried through a red-hot gauze into a lamp, and, having therein become incandescent, to pass through the gauze out of the lamp and fire the gas outside; but it seemed to him that, if a lamp were made red-hot by a low-velocity current con-

taining fire-damp, any coal-dust mixed with such current would be immediately inflamed on contact with the red-hot gauze, and so might cause an explosion. Mr. John Gerrard had called attention to the introduction into Lancashire mines of a lamp which was giving him anxiety, as he did not consider that it was safe. From what he could see of the lamp, his (Mr. Bramall's) opinion coincided with that of Mr. Gerrard, and he certainly would not be prepared to adopt it, or even try it, without satisfactory tests being applied. He entirely agreed with Mr. Gerrard's suggestion that safety-lamps ought to be, in some manner authoritatively tested, but he was scarcely prepared to go so far as to suggest that the Government should have power to order the use of any special type of lamp. He certainly thought that the Government ought to establish a lamp-testing station or stations, which might be placed under the supervision of a committee composed, say, of some of the inspectors of mines and some of the leading mining engineers. Lamps should be tested as to their safety exactly as explosives are now tested, and the Government might issue a list of authorized or "permitted" safety-lamps. What had been done hitherto had been chiefly left to private enterprize, but if any pressure could be brought to bear on the Government to induce it to establish lamp-testing stations it would be very beneficial. They might issue detailed specifications of the dimensions of the best types of lamps and particulars of their construction describing the forms and sizes which were safe. Such details would meet the point to which Mr. Winstanley had called attention, and so unscientific lamp-makers would be able to make lamps in accordance with those instructions and that would be a distinct gain. It would appear, at present, that it was quite possible for a manufacturer to make and put on the market almost any kind of lamp and call it a safety-lamp, and even to patent it, although it might be defective and a dangerous lamp to use; and, as Mr. Gerrard had pointed out, colliery owners might introduce these faulty or unsafe lamps into pits. He thought, however, that if the lamps which were coming into use were dangerous, it was time that the Government took some action. His impression was that an inspector of mines could object to any appliance found in a pit, if in his judgment it was unsafe; and, if the mine-owner persisted in its use, the matter would be referred to arbitration. The inspector of mines might not have the power actually to forbid the use of any lamp

which he did not consider safe; but no doubt a recommendation from him would be seriously considered and he suggested that the inspectors of mines ought, in the first instance, to take that course. If, thereafter, an owner was contumacious, he thought that the inspector of mines would be justified in taking stronger measures. This was a question of very serious moment, and action ought not to be deferred until there was an explosion and men were killed.

Mr. James Ashworth, replying to the discussion, again expressed his agreement with the suggestion made by the Royal Commission on Accidents in Mines that the Government should establish a testing station for safety-lamps; and the cost would be trifling in comparison with the importance of the issues at stake. His object in writing the paper was to call public attention to certain important matters which had not received due consideration. He thought it unfair to condemn the bonneted Clanny lamp used at Clydach Vale colliery before the Davy lamp used by D. Enoch had been found and examined; and the condemnation seemed to him to have no sound basis. Mr. F. A. Gray said that the lamp was found under some debris; while he (Mr. Ashworth) stated that he had heard that parts were found in three separate places and he, therefore, thought that the condemnation was premature.

The coal-dust was so small that it could go into and out of the gauze, and when making tests with mixtures of air, gas and coal-dust, it was not necessary for the gauze to become very hot to cause a lamp to fail; it required only a small amount of coal-dust to carry the flame very quickly through the gauze. He did not know why the Royal Commission on Explosions from Coal-dust in Mines did not make experiments on safety-lamps with coal-dust, unless they were debarred by the cost, or thought that it was an unnecessary investigation.

The Belgian authorities had settled that a Mueseler safety-lamp chimney of certain dimensions was the safest form, but it had since been proved that the English construction of chimney was better than the Belgian form. Mr. J. B. Marsaut had proved that the explosion-flame did not pass up the chimney, but through the gauze at its base. He (Mr. Ashworth) had no hesitation in saying that the English form of Mueseler chimney was safer than the Belgian form in a fiery place.

THE MIDLAND COUNTIES INSTITUTION OF ENGINEERS.

GENERAL MEETING,
HELD AT THE CASTLE HOTEL, TAMWORTH, DECEMBER 2ND, 1905.

MR. W. G. PHILLIPS, PRESIDENT, IN THE CHAIR.

DEATH OF MR. GEORGE LEWIS, DERBY.

The PRESIDENT (Mr. W. G. Phillips) said that he had a very painful duty to perform. Probably all of the members were aware that since their last meeting the Institution had sustained a great loss in the death of one of its oldest and most esteemed members, Mr. George Lewis, of Derby. He was not sure whether Mr. Lewis was one of the founders or no, but if not he was a very early member, and during the whole time of his connection with the Institution he had always given to it of his very best, to its great interest and advantage. He had filled the position of President of the Institution, and had moreover been President of The Institution of Mining Engineers; and he thought that it was their bounden duty to show their respect to the memory of Mr. Lewis. He proposed to send, on their behalf, a letter of condolence to the family, and he asked them to express their approval of that course by standing up.

The resolution was carried in silence, all the members rising.

Mr. G. ALFRED LEWIS said that he desired to express on his own behalf his sincere thanks for their kind resolution, and to say that he was sure that the members of the family would be very pleased indeed to receive such an expression of sympathy. His father, as everyone knew, took an exceedingly great interest in the welfare of the Institution, and it was most gratifying to hear that his services had been valued in the way that they had.

The SECRETARY announced the election of the following gentlemen: —

MEMBERS—

Mr. HERBERT CHAPMAN, Surveyor, Wales Road, Kiveton Park, Sheffield.

Mr. ROBERT WILLIAM CUTHBERTSON, Colliery Manager, Duckmanton, near Chesterfield.

Mr. JOHN GREENSMITH, Colliery Manager, Holly Bank House, Norbriggs, Chesterfield.

Mr. HENRY HERBIN JACKSON, Mining Engineer, Halesowen, Birmingham.

Mr. JAMES LANCASTER, Mining Engineer, Forest Ville Lodge, Nottingham.

Professor WILLIAM ROBINSON, M.E., M.Inst.C.E., Professor of Engineering, University College, Nottingham.

Captain WILLIAM SHERBROOKE, Owner and Lessor of Mineral Estates, Oxton Hall, Southwell.

Mr. JAMES EVELYN VAUGHAN, Mines Inspector, Winchester House, Johannesburg, S.A.

Mr. CHARLES WILLIAM WRIGHT, Estate and Mineral Agent, 21, Parkinson Street, Nottingham.

ASSOCIATES—

Mr. JAMES ALLCOCK, Underground Haulage-contractor, 132, New Bolsover, near Chesterfield.

Mr. E. ROBINSON, Electrical Engineer, Eckington Collieries, Sheffield.

Mr. JAMES TAYLOR, Foreman Carpenter and Student, c/o Messrs. Barber, Walker and Company, Beggarlea, Nottingham.

Mr. JAMES THOMPSON, Electrical Engineer, Oxclose Villa, Mansfield Woodhouse, Notts.

Mr. JONATHAN PIGGFORD'S paper on "The Two-stage Air-compressing Plant at Teversal Collieries" was read as follows: —

THE TWO-STAGE AIR-COMPRESSING PLANT AT TEVERSAL COLLIERIES.

By JONATHAN PIGGFORD.

Introduction.—Up to seven years ago, the compressed-air plant consisted only of the machinery described in section A of Table I., and it was then found necessary to add section B. This increase practically absorbed the whole of the surplus power, and if from any cause the requirements were more than normal, there was no means of supplying the deficiency.

TABLE I.—AIR-COMPRESSORS AND COMPRESSED-AIR ENGINES AT TEVERSAL COLLIERIES.

Section of Plant.	No. of Machines.	Description of Machines.	No. of Cylinders.	Diameter of Cylinders. Steam.	Diameter of Cylinders. Air.	Diameter of Cylinders. Water.	Stroke of Piston.	Diameter and Weight of Flywheels. Diameter.	Diameter and Weight of Flywheels. Weight.	Diameter of Gear-wheels, etc. Pinion.	Diameter of Gear-wheels, etc. Spur.	Diameter of Gear-wheels, etc. Rope-driven.	Number and Size of Air-valves. Inlet. No.	Number and Size of Air-valves. Inlet. Dia.	Number and Size of Air-valves. Outlet. No.	Number and Size of Air-valves. Outlet. Dia.
				Ins.	Ins.	Ins.	Ins.	Ins.	Lbs.	Ins.	Ins.	Ins.		Ins.		Ins.
A	1	Low-pressure air-compressor ..	4	36	38	..	72	242	33,600	..	..	..	40	4	4	*
	2	Haulage-engine	2	..	20	..	42	93	6,720	22	87	73	..	..	..	..
	3	Cameron pump ..	2	..	7	$2\frac{1}{4}$	6	36	1,120	..	..	..	..	..	..	..
	4	Cameron pump ..	2	..	$8\frac{1}{2}$	$3\frac{3}{4}$	6	45	1,568	..	..	..	..	..	..	..
	5	Worthington pump	2	..	$5\frac{1}{4}$	2	5	..	..	..	..	..	..	..	..	..
B	6	Haulage-engine ..	2	..	14	..	22	73	..	17	80	73	..	..	..	..
C	7	High-pressure air-compressor ..	4	20	22	..	24	96	6,720	..	..	..	20	4	20	3
	8	Worthington pump	..	..	..	..	..	..	..	..	..	..	..		..	*

* 20 inches by $1\frac{1}{2}$ inches.

For the purpose of remedying this shortage of power, and with a view to avoid as far as possible heavy expenditure of capital, a series of experiments were made, in order to see what effect the heating of the compressed air just before using it in the cylinders of the motors would have, towards helping to overcome the difficulty. It was found that, by passing the air through a small furnace fed with coke, and placed in close proximity to the motor, it was possible, with a comparatively small expenditure of fuel, to increase the horsepower by 10 per cent.

Air-heater.—This result encouraged the author to carry the experiments a step further, for the purpose of which, a special form of heater was put down, the type adopted being that shown in Figs. 1 and 2 (Plate XII.). It is constructed of two cast-iron shells bolted together, and so enclosing an annular space through which the compressed air is conveyed and spread out into a thin sheet, thus affording an easy means of applying heat to it, with a corresponding economy in the consumption of fuel. In order to obtain the best possible result, the heater should be placed as near as can be to the point where the air has to be used, and should also be well covered with some good non-conducting material, so as to avoid loss of temperature. In the author's case, the heater is placed immediately behind the cylinders of the motor, and by its introduction the efficiency has been increased by 28 per cent.

Laidlow-Dunn-Gordon Air-compressor.—The increased power satisfied, for the time being, the requirements of the colliery, but as the haulage-roads advanced, and it also became necessary to develop a new district in the direction of the full dip of the measures, an absolute necessity arose for considerably increased power. Inasmuch as the air-compressing plant described in section A of Table I. was not adaptable for higher speed or higher pressure, it was decided to meet the requirement by adopting a system of two-stage compression; and for this purpose the author has recently erected a Laidlow-Dunn-Gordon duplex fork-frame air-compressor, Figs. 3 and 4 (Plate XII.), consisting of two steam-cylinders, each 20 inches in diameter, and two air-cylinders, each 22 inches in diameter, with a stroke common to both of 24 inches, as described in section C of Table I. This plant is capable of producing, when running at 90 revolutions per minute, an air-displacement of 21 cubic feet per revolution, or 1,890 cubic feet per minute, with a steam-pressure of 50 pounds and an air-pressure of 60 pounds per square inch.

By this supplement of power and the introduction of water-cooling appliances, the author has been able to overcome some of the serious loss, due to the increased temperature, which would have been in the air, if he had attempted to obtain this volume and pressure in one stage. Because in the latter process, little or no heat can be taken from the air during compression, hence

the temperature rises, and as a given weight of air at a given pressure occupies a space proportional to its temperature, it follows that the volume at all pressures must necessarily be greater under the system of adiabatic compression, than it would be under any other system approaching isothermal compression. For instance, when compressing air under adiabatic conditions, the volume has been reduced to one-half, the pressure will not only be doubled as in isothermal compression, but more than doubled, in consequence of the heat which is generated during the compression being still retained in the air.

Intercooler.—Economy, therefore, consists in abstracting this heat to the greatest possible extent, and in order to obtain all possible in this direction, water-jackets are applied to the air-cylinders in both stages of compression, and the air from the low-pressure cylinders is passed through an intercooler before introducing it into the high-pressure cylinders. As this intercooler plays a most important part in stage-compression, it is false economy not to provide one of ample size; and, unless a good margin of cooling-surface is provided, the efficiency of the whole plant is much reduced. The construction of the intercooler is similar to that of a modern surface-condenser (Figs. 5 and 6, Plate XII.), and consists of a circular pipe, inside of which are placed 121 small brass tubes, $\frac{11}{32}$ inch in diameter, through which water circulates in a direction contrary to that of the air outside them. The tubes break up the stream of air, and their thin walls induce rapid conduction of the heat of the air. The outer shell also forms a receiver for accumulating a volume of air, and thus provides a means for securing a nearly uniform discharge-pressure. The air, also, being outside of the small water-tubes, meets but little frictional resistance; and, if the intercooler be of sufficient size, the low velocity of the air in passing through it affords sufficient time for thorough cooling.

Two-stage Air-compression.—Although, owing to increased heat, increased pressure in the air can only be obtained at the expense of efficiency, the loss can be considerably lessened by doing the work in stages. During the first stage, the air is compressed to about 25 pounds to the square inch, and it is cooled, as much as possible, during the process. The air is then passed through the intercooler, and, in this way, the heat is

reduced, the second stage commencing at a comparatively low temperature, and the air is then raised to the required pressure: the temperature, at this point, being much lower than it would have been if the air had been compressed adiabatically and in one stage. The great advantage effected by this abstraction of heat is shown graphically in Fig. 7 (Plate XII.), which represents compression by two stages, in which no cooling medium is used, except when the air is being conveyed from the low-pressure to the high-pressure cylinder, through an efficient intercooler.

During the first stage, compression follows the adiabatic curve, AD: the loss of power being shown by the shaded area, AED, and the volume of air at this point being represented by DG. This finishes the first stage, and the air is then passed through the intercooler, and its volume is reduced to EG; the latter, supposing that all the heat could be extracted, would then be on the isothermal line. The second stage now proceeds along the adiabatic curve, EF: the waste of power in this stage being shown by the shaded portion of the area, EFC. Now, if the whole of the work had been performed in one stage, the loss of power would have been indicated by the area, AIC; whereas, by two-stage compression, it is represented by the areas, ADE and EFC; and the saving is shown by the area, DIFE.

In addition to the loss in compression, there are others due to the cooling of the air during transit, and that arising from friction and leakage in the pipes. The efficiency of the whole plant is also largely governed by the manner in which the air is used in the motor, because if a proper amount of expansion be arranged, the loss of efficiency is materially reduced, especially so, if the air can be heated, as previously described, before using it in the motor, so as to recover as much as possible of the loss sustained in the mains. Unfortunately, however, there is a serious drawback to working air expansively, whenever re-heating of the air is impracticable, because as in adiabatic compression a rise of temperature takes place, so in adiabatic expansion the reserve occurs. In consequence of this, at the end of the stroke, the air becomes exceedingly cold, and unless liberal allowance has been made in the size of the exhaust-ports of the motor-cylinders, trouble will arise, because of the freezing of the moisture contained in the air, and the passages become

blocked with ice. Now, as increased pressure entails decreased efficiency, it would appear that the pressure used should be low; but to this there is also an insuperable objection, in the shape of the increased initial cost of the plant, inasmuch as the lower the pressure that is used, the larger must be the compressing plant, and also the motors which use the air. Therefore, whatever might be gained in enhanced working efficiency by the adoption of a low pressure, would be more than counterbalanced by the extra capital-charges necessary to provide the larger plant.

Second-stage Air-compressor.—The general arrangements of the old and new plant at the Teversal collieries is shown in Figs. 9, 10 and 11 (Plate XIII.). The steam- and air-cylinders of the second-stage or intensifier are placed in tandem (Figs. 3 and 4, Plate XII.), the jointings and perfect alignment being secured by rigid cast-iron housings, matching tongues and grooves. The housings are of such a length as to allow of easy withdrawal of the pistons for examination or renewal. The pistons are of cast-iron, and fitted with Harris-Corless self-adjusting packing-rings. The engines are fitted with Meyer valve-gear, and steam-distribution is effected by the main-valve, driven by an eccentric on the main-shaft. Upon the back of the main-valve, and driven by an independent eccentric-rod, are two cut-off valves, and their distance apart determines the point of cut-off. This distance, and consequently the point of cut-off, is made variable within wide limits, by means of a stationary hand mounted upon the rear-end of the steam-chest: a pointer being carried upon the hand-wheel bracket to indicate the point in the stroke at which the cut-off is taking place. Full provision is made for the outside adjustment of the valves.

A combined speed-and-pressure governor maintains the compressor at constant speed, while the air-pressure remains below the desired maximum; and the engine is fitted with an auxiliary device reducing the steam-supply, when the pressure-limit is reached, thus preventing any excess of that pressure.

The frame of the engine is of the forked type, two bearings being located on each side of the crank, preventing any swinging motion of the shaft, and ensuring light and even wearing on the bearings, and perfect adjustment of all parts. The bearings are of the quarter type, fully adjustable for wear, and lined

with babbitt-metal. The crossheads work in bored slides. The shaft-crank and crank-pin are made in one piece, out of high-grade steel: this construction giving a high degree of strength, rigidity and durability. The connecting-rod is of steel, the crank-pin end being of the strap-pattern, with babbitted brass-boxes. The crosshead end is solid, and both ends are provided with wedge-and-screw adjustment. The crosshead is of iron, of box pattern, fitted at the top and bottom with adjustable babbitt slippers: the pin being taper-fitted to the crosshead and easily removed. The flywheel-rim is square in section.

Water-jacketting surrounds the air-cylinders, and the coring is so arranged as to ensure thorough and effective circulation of the water. The construction of the heads and connecting housings are such that all joints may be broken or removed, without disturbances of other parts (Figs. 12 and 13, Plate XIII.).

The air suction-valves are enclosed, and suction-ports are provided for ensuring quiet suction, and permitting the air to be drawn from the coolest convenient source. The clearance-spaces are as small as possible, the heads and pistons being faced so as to ensure a minimum clearance. The air-valves of the compressors are of the poppit type and located in the cylinder-head; they are self-contained, the valves and seats forming a complete whole, and depending for their proper working upon the fit and adjustment of no other part. This construction permits of easy removal of the valves for cleaning or regrinding. The valve-seats are screwed into their places with a fine thread, the discharge-valves are locked in position with set screws, and a light perforated guard-plate covers the valve-openings (Figs. 14 and 15, Plate XIII.).

Air-pipes.—The compressed air is taken down the pit through cast-iron pipes, 10 inches in diameter. At the bottom, a breeches-pipe is fixed, from which two branches proceed, one running in a northerly direction to the No. 2 haulage-motor and Nos. 3, 4 and 5 pumps; and the other in a southerly direction to the No. 6 haulage-motor and No. 8 pump (Fig. 8, Plate XII.). These pipes are made of cast-iron, 9 inches in diameter, with socket-joints. The pipes to the No. 2 haulage-motor are ordinary castings, the joints being made with lead or iron filings, whereas those to the No. 6 haulage-motor are turned

and bored at the ends, the joints being made by simply rubbing a little red lead round the small end of the pipe, before introducing it into the socket, and then driving the pipe home with a heavy wooden mallet. The latter mode of jointing is much superior to the former, the work is more rapidly done, more reliable when done, and, so far as the author is concerned, has never caused the slightest trouble.

Careful efficiency-tests of the whole system of air-compression have been made, with the results recorded in the appendix.

Mechanical Efficiency.—The mechanical efficiency is the ratio of the work performed on the air to the work done by the steam. The work performed by the steam, as shown by the indicator-cards in the steam-cylinders of the low-pressure engine was 277·96 horsepower, and in the steam-cylinders of the high-pressure engine, 182·54 horsepower: a total of 460·50 horsepower. The work performed on the air, as shown by the indicator-cards in the air-cylinders of the low-pressure engine was 238·06 horsepower, and in the air-cylinder of the high-pressure engine, 174·66 horsepower: a total of 412·72 horsepower. Hence, the mechanical efficiency is [$(412·72 \div 460·50) \times 100$ or] 89·62 per cent.

Volumetric Efficiency.—The volumetric efficiency is the ratio of the volume of air actually delivered to the volume swept out by the pistons. The diameters of the low-pressure and high-pressure cylinders are 38 inches and 22 inches respectively, the piston-rods of the former being 6 inches and of the latter $2\frac{3}{4}$ inches in diameter; therefore, the net volume swept out by the piston of the low-pressure engine will be [$(38^2 \times 0·7854 \times 72) \div 1728 - (6^2 \times 0·7854 \times 72) \div 1728$ or] 46·07 cubic feet per stroke of each of the pistons. In the same way, the volume discharged from each of the cylinders of the high-pressure engine will be [$(22^2 \times 0·7854 \times 24) \div 1728 - (2·75^2 \times 0·7854 \times 24) \div 1728$ or] 5·19 cubic feet per stroke of each of the pistons.

It was found, by careful measurement, that 600 cubic feet of high-pressure air were delivered into the storage-receivers per minute.

The volume of air swept out of each of the cylinders of the low-pressure engine was 46·07 cubic feet per stroke, and as the

speed of these compressors during the tests was 18 revolutions per minute or 36 single strokes, the total volume discharged by the two cylinders of the low-pressure engine in 1 minute was ($46.07 \times 36 \times 2$ or) 3,317·04 cubic feet. The pressure of the air at the end of the suction-stroke was 14·7 pounds per square inch absolute, and its temperature 72° Fahr.

The volume of air discharged from the cylinders of the high-pressure engine into the receiver was 600 cubic feet per minute; the mean temperature of this air was 150° Fahr. or 611° absolute; and the pressure of this air was 74·7 pounds per square inch absolute. The volume swept out by the pistons of the low-pressure engine was 3,317·04 cubic feet per minute; the mean temperature of this air was 72° Fahr., or 533° absolute; and the mean pressure of this air was 14·7 pounds per square inch absolute. These statements must now be reduced to the same pressure and temperature, in order to compare fairly the volumes. In any given volume of air $P \times V \div T$ equals a constant: P, being its absolute pressure; V, its volume; and T, its absolute temperature. Then taking P to represent the absolute pressure of the air; V, its volume; and T, its absolute temperature; and making P', V' and T' these values for the cylinder-air; and P'', V'' and T'' the same for the air inside the receivers, it follows that:—

$$\frac{P'V'}{T'} = \frac{P''V''}{T''} \text{ and } V'' = V' \frac{P'\,T''}{P''\,T'}.$$

Therefore, [$(3{,}317.04 \times 14.7 \times 611) \div (74.7 \times 533)$ or] 748·27 cubic feet is the volume of air that should have been delivered into the receiver, if there had been no leakage or clearance-losses. The actual delivered quantity was only 600 cubic feet, and, therefore, the volumetric efficiency is [$(600 \times 100) \div 748.27$ or] 80·18 per cent.

Efficiency of Compression.—The efficiency of compression is the ratio of the work which would be performed in compressing the air isothermally to that actually required to compress the same volume of air, under existing conditions. The pressure of the air at the beginning of the compressing stroke in the cylinders of the low-pressure engine was 14·7 pounds per square inch, and it was raised in these cylinders to 39·7 pounds per square inch absolute. The clearance-volume in the cylinders of the low-

pressure engine is 2 per cent. of the volume swept out or 0·92 cubic foot, and this volume must expand isothermally from the higher pressure of 39·7 pounds per square inch to the lower pressure of 14·7 pounds; and, at the end, the volume would be (0·92 × 39·7 ÷ 14·7 or) 2·48 cubic feet. It is not until this re-expansion has occurred, that the real suction begins, consequently the actual suction-volume is only (46·07 + 0·92 − 2·48 or) 44·51 cubic feet.

In the cylinders of the high-pressure engine, the clearance-volume is 1 per cent. or 0·052 cubic foot. The initial pressure at the beginning of compression was 39·7 pounds per square inch absolute, and the final pressure 74·7 pounds per square inch absolute, therefore, this volume becomes (0·052 × 74·7 ÷ 39·7 or) 0·098 cubic foot; and the actual volume discharged is (5·19 + 0·052 − 0·098 or) 5·14 cubic feet.

The work in foot-pounds required to draw in, compress isothermally and discharge a given volume, V′, from an initial pressure, P′, to a final pressure, P″, is expressed by the formula $P'V' \log_e \frac{P''}{P'}$. In the present case, the ratio of P″ to P′ is as 39·7 is to 14·7 or 2·7, and its hyperbolic logarithm is 0·9933; and as P′ is 14·7 and V′ 44·51, the work is (14·7 × 44·51 × 144 × 0·9933 or) 93,587·5 foot-pounds per stroke. These compressors make 36 single strokes per minute, and as there are two cylinders, the power required to compress this air isothermally would be (93,587·5 × 36 × 2 ÷ 33,000 or) 204·19 horsepower. The actual horsepower, however, developed in the air-cylinders of the low-pressure engine was 238·06; and, therefore, the efficiency of compression in the low-pressure engine is (204·19 × 100 ÷ 238·06 or) 85·77 per cent.

Going over the same lines of calculation for the high-pressure engine, the pressure at the beginning of the stroke of compression was 39·7 pounds per square inch absolute, and the pressure at the end was 74·7 pounds per square inch absolute; and, therefore, the ratio of P″ to P′ in this case is as 74·7 is to 39·7 or 1·88, and its hyperbolic logarithm is 0·6313. The work is, therefore, (39·7 × 5·14 × 144 × 0·6313 or) 18,550·34 foot-pounds per stroke. These compressors make 120 single strokes per minute, and as there are two cylinders, the power required to compress this air isothermally would be (18,550·34 × 120 × 2 ÷

33,000 or) 134·91 horsepower. The actual horsepower developed was 174·66; and, therefore, the efficiency of compression in the cylinders of the high-pressure engine is (134·91 × 100 ÷ 174·66 or) 77·24 per cent.

Efficiency of Compression for the Whole Process.—The available data for this calculation are as follows:—The mean pressure of air in the receivers, 74·7 pounds per square inch absolute; the mean pressure of the atmosphere from barometer-readings, 14·7 pounds per square inch; the quantity of air delivered to the receiver was 600 cubic feet per minute; the temperature of this air was 611° Fahr. absolute; and the temperature of the air of the atmosphere was 521° Fahr. absolute.

The quantity of free air, V′, taken into the cylinders of the low-pressure engine is [(600 × 74·7 × 521) ÷ (14·7 × 611) or)] 2,599·86 cubic feet. The total isothermal work will be $V'P' \log_e 74{\cdot}7/14{\cdot}7 \div 33{,}000$ or (14·7 × 2,599·86 × 144 × 1·6258 ÷ 33,000 or) 271·05 horsepower. The indicated horsepower was 412·72; and, therefore, the efficiency of compression for the whole process is (271·05 × 100 ÷ 412·72 or) 65·67 per cent.

Ratio of the Horsepower in the Steam-cylinders at the Compressors and the Horsepower developed at the Motors.—The power developed at the six motors is as follows:—No. 2 haulage-engine, 116·76 horsepower; No. 3 pump, 3·60 horsepower; No. 4 pump, 5·40 horsepower; No. 5 pump, 1·60 horsepower; No. 6 haulage-engine, 61·80 horsepower; No. 8 pump, 0·90 horsepower: a total at the motors of 190·06 horsepower. The indicated horsepower in the steam-cylinders at the compressors was 460·50; and, therefore, the total efficiency as between the steam at the compressors and the air at the motors is (190·06 × 100 ÷ 460·50 or) 41·27 per cent.

This result, taking into account the conditions under which the alterations had to be carried out, may be considered as fairly satisfactory; and, of course, a higher percentage of efficiency could have been attained if the old plant had not had to be considered. This, however, was the primary consideration, the object being to gain what was required at the lowest possible

expense, and this, the author thinks, has been successfully accomplished.

With modern engines of the most economical type; good air-valves mechanically controlled; a minimum of clearance in the compressing cylinders; the compressors running at high speeds and the work done in stages; and ample cooling devices; coupled with the re-heating of the air before passing it into the motors, and then using it expansively; there is no reason whatever, why air-compressors should not yield a satisfactory efficiency.

APPENDIX.—Results of Experiments upon the Air-Compressing Plant.

1. The low-pressure engine, with two steam-cylinders, each 36 inches in diameter and 6 feet stroke, made 18 revolutions per minute, with an average pressure of 20·86 pounds per square inch, and developed 277·96 horsepower.

The low-pressure engine with two air-cylinders, each 38 inches in diameter and 6 feet stroke, made 18 revolutions per minute, with an average pressure of 16·035 pounds per square inch, and developed 238·06 horsepower.

2. The high-pressure engine, with two steam-cylinders, each 20 inches in diameter and 2 feet stroke, made 60 revolutions per minute, with an average pressure of 39·95 pounds per square inch, and developed 182·54 horsepower.

The high-pressure engine, with two air-cylinders, each 22 inches in diameter and 2 feet stroke, made 60 revolutions per minute, with an average pressure of 31·59 pounds per square inch, and developed 174·66 horsepower.

The mechanical efficiency of the compressing-plant was 89·62 per cent.

The volume swept out of each of the air-cylinders of the low-pressure engine was 46·07 cubic feet per stroke.

The pressure of this air at the end of the suction-stroke was 14·7 pounds per square inch absolute. The temperature of this air was 72° Fahr., or 533° absolute.

The volume of air discharged from the cylinders of the high-pressure engine into the receiver was 600 cubic feet per minute. The mean temperature of this air was 150° Fahr., or 611° absolute. The pressure of this air was 74·7 pounds per square inch absolute.

The volume of air swept out by the pistons of the low-pressure engine was 3,317·04 cubic feet per minute. The mean pressure of this air was 14·7 pounds per square inch absolute, and its mean temperature was 72° Fahr., or 533° absolute. The temperature of the atmosphere was 60° Fahr., or 521° absolute. This air was raised in the air-cylinders of the low-pressure engine to a pressure of 39·7 pounds per square inch absolute.

The volumetric efficiency was 80·18 per cent.

The ratio of the compression in the air-cylinders of the low-pressure engine was 2·7. The efficiency of the compression in the air-cylinders of the low-pressure engine was 85·77 per cent.

The ratio of the compression in the air-cylinders of the high-pressure engine was 1·88. The efficiency of the compression in the air-cylinders of the high-pressure engine was 77·24 per cent.

The efficiency of the compression for the whole process was 65·67 per cent.

3. The No. 2 haulage-engine, with two cylinders, each 20 inches in diameter and 3½ feet stroke, made 42 revolutions per minute, with an average pressure of 20·86 pounds per square inch, and developed 116·76 horsepower.

4. The No. 6 haulage-engine, with two cylinders, each 14 inches in diameter and 22 inches stroke, made 120 revolutions per minute, with an average pressure of 15·055 pounds per square inch, and developed 61·80 horsepower.

The mechanical efficiency for the whole process was 41·27 per cent.

The PRESIDENT (Mr. W. G. Phillips) moved a cordial vote of thanks to Mr. Piggford for his paper.

The resolution was approved, and the discussion of the paper was adjourned.

DISCUSSION OF PAPERS ON "THE ACTION, INFLUENCE AND CONTROL OF THE ROOF IN LONGWALL WORKING," BY MESSRS. H. W. G. HALBAUM,* J. T. BEARD† AND E. H. ROBERTON.‡

Mr. H. R. HEWITT wrote that the number of fatalities during 1904 from falls in mines numbered 48·2 per cent. of the total fatalities, and he thought that this matter was so important that one of the general meetings might be fully employed in discussing these papers alone. When we hear that the maximum distance for props fixed by the manager, under the Special Rules, is 10 or more feet, it appears that not all managers have yet learned their responsibilities, and their capabilities appear to qualify them for working side by side with the workmen in such places, so that their education may be more complete. If such managers would inform the examiners, when they sat for a certificate, that if they were successful at the examination their efforts would be directed to evasion of the Coal-mines Regulation Act and its obligations, it would be the more honest course to pursue. He quite agreed with Mr. Halbaum's reasoning on this subject, and would like to emphasize the conclusion to which he had come regarding the building of packs and the setting of timber, which should be done with "the utmost promptitude." The width of the packs, he agreed, should be greater accordingly

* *Trans. Inst. M. E.*, 1904, vol. xxvii., page 205; vol. xxviii., page 316; and vol. xxix., page 3.

† *Ibid.*, 1904, vol. xxviii, page 341.

‡ *Ibid.*, 1905, vol. xxix., page 5.

as the height of the seam is greater, and no pack in a longwall-face should be less than 9 feet in width, a width which is too frequently used as a maximum in seams of all thicknesses. The use of wooden chocks on the rise side of roadways going across the dip assists to hold the pack-wall in position, and such chocks have been successfully used in seams rising at a considerable inclination. He feared that they must wait a long time before finding the ideal prop which will give itself to the weight put upon it, and he suggested a more general adoption of "herring-bone" or Gothic timbering in roadways of considerable width and height. In the discussion of Mr. Halbaum's paper, it was admitted that the men of the north of England knew nothing of the subject in its proper form, and that they must go to the southern and midland counties to see how Mr. Halbaum had drawn his deductions,* so that there was something yet to be learned by those members from us. Mr. Beard called the travelling weight by the name of "underweight," which appeared to be a curious way of explaining what they knew as "top-weight," and, to his mind, expressed exactly what occurs in working coal by the longwall method. If we get "under-weight" we call it "creep," which is seldom seen in the working-face, and cannot be used in assisting to get the coal. In Mr. Beard's plans,† the packs appeared to be 60 feet from the working-face, which cannot be allowed under proper management, as it is highly necessary that all packs should be kept as close up as possible. Mr. Beard fails to understand the subject when he says "less timber throws more weight on the face of coal, while more timber decreases this weight." The timbering and packing of the stalls should be well done, so that the weight may be carried over the coal-face in order to assist the process of coal-getting, and if the roof cuts off at the edge of the face it is a sign that this is not being done. Mr. Roberton describes the many difficulties that he encountered through not understanding the work and not laying out his pit to the best advantage.

Mr. J. A. LONGDEN's paper on "Colliery-consumption" was then read as follows:—

* *Trans. Inst. M. E.*, 1905, vol. xxviii., page 321.

† *Ibid.*, 1905, vol. xxviii., page 346, Plate X., Fig. 3.

COLLIERY-CONSUMPTION.

By J. A. LONGDEN.

The Council of The Institution of Mining Engineers were good enough to give the author a prize for his paper on the above subject in 1899;* and he thinks that the subject is of such vital interest to all connected with collieries, that he ventures to supplement his former remarks by some actual results obtained at one of the pits belonging to the Stanton Ironworks Company.

The output in 1892 was 283,000 tons, and the colliery-consumption was 7½ per cent. The output, now, is 560,000 tons, and the colliery-consumption is 3 per cent.

Someone says that this is not a very remarkable performance, and perhaps not equal to those pits where there is an abundance of water to condense all the steam. But what does a reduction in the colliery-consumption from 7½ to 3 per cent. mean, upon an output of 560,000 tons per annum? The author will assume that the average selling-price is 6s. per ton for sales and 1s. per ton for colliery-consumption; in the one case, the average selling-price is 5s. 10¼d. and in the other 5s. 7½d. per ton. The difference of 2¾d. on 560,000 tons equals £6,450 per annum; and nothing has been added for the saving effected by using only half the number of boilers, and a consequently decreased number of stokers.

When the members learn that Caddy bars, Bennis stokers, Proctor stokers, Empire stokers, underfeed stokers and Meldrum furnaces have all been tried and discarded, and that this result has been obtained by hand-firing, it is evident that the mechanical stoker has not to be thanked for any supposed benefit.

The question naturally arises, how has the saving been effected? In 1892 there were 16 Cornish boilers, and as the output increased, they were replaced by 16 small second-hand Lancashire boilers, worked at a pressure of 60 pounds per square inch.

* *Trans. Inst. M. E.*, 1898, vol. xvi., page 366.

In the course of time, it became evident that the winding-engines were too weak; and, one after the other, both winding-engines were taken out, and stronger engines put in, capable of working with steam at a pressure of 100 pounds per square inch. Then, the author found that whilst it had taken 16 small Lancashire boilers working at a pressure of 60 pounds per square inch, the same work could now be done with 10 large Lancashire boilers, worked at a pressure of 100 pounds per square inch. And to this change, the great economy may be attributed.

A further attempt was made to reduce the consumption by putting balance-ropes under the chairs, but these have both been taken off, as the author found that the guides were badly worn; and, curiously enough, the author could not find any appreciable saving in fuel.

The whole of these alterations were made without losing a day's coal-turning, as one pit worked night-and-day while the other pit was undergoing alterations.

Thirty years' experience has clearly demonstrated the value of the overtop covering and trellis-firebrick-work under boilers, so clearly advocated by the author in 1876.*

No doubt, some of the new collieries, with enormous capital expenditure, will put down Mond gas-plants, which give out one horsepower with a consumption of $\frac{3}{4}$ pound of slack; this, in a good gas-engine, can drive a generator, and thus bring the colliery-consumption to a minimum; and, if a bye-product plant be put up, the residuals will pay for the cost of the fuel used, and then our highest ambition is attained: no charge, whatever, for colliery-consumption.

Mr. George Spencer (West Hallam) said that Mr. Longden was undoubtedly to be congratulated on reducing the consumption from $7\frac{1}{2}$ to 3 per cent. There were certain portions of colliery-consumption, such, for instance, as that for pumping, which were constants, and when spread over the much larger output probably accounted for some of the economy which had been effected. The economy reduced to money-value, however (stated to be £6,450), seemed to be so great as to suggest that an analysis of the figures was called for. In checking these by

* "The Evaporative Power of Lancashire Boilers," *Transactions of the Midland Counties Institution of Engineers*, 1876, vol. iv., page 22.

a direct method, that was, by taking the difference between 7½ and 3 per cent., or a saving of 4½ per cent. on 560,000 tons at 1s. per ton, it would be found to work out at £1,200 only, and not at £6,450. He would ask whether these figures did not disclose an error in Mr. Longden's conclusions, and whether it would not be found to lie in the erroneous assumption that the value of the boiler-fuel saved was 5s. 10¼d. per ton instead of 1s. per ton. There was a clear saving of 25,200 tons on the original percentage, but would not that be a saving of slack only, and not of coal of the higher value? Economy at the boilers did not affect the quantity of slack turned out of the pit with the coal. Even allowing that the present boiler-consumption was still 7½ per cent., or 42,000 tons on the present output of 560,000 tons, the value would amount to only £2,100 at 1s. per ton, the price assumed by Mr. Longden, whereas the author claimed to have effected economies to the extent of £6,450. The value of the slack thrown upon the market was not stated, but to make up the amount of saving shown by Mr. Longden the average all round would have to be 5s. 10¼d. per ton,

Mr. W. Price Abell (Duffield, Derby) remarked how greatly indebted the members were to Mr. Longden for his persistent advocacy of economy in this direction. At the same time he did not think that Mr. Longden intended to convey what might be understood as being a condemnation of mechanical stokers; when he stated " it is evident that the mechanical stoker has not to be thanked for any supposed benefit," but he thought that Mr. Longden applied this remark only to the particular plant under consideration. Of course, it is an axiom that the maximum of efficiency is obtained by watching every leak and studying every economy on commercial lines, and if one or two items are omitted, then, of course, a maximum of economy is not being obtained. He ventured to say that there could not be the slightest doubt as to the economy accruing from the use of good mechanical stokers: and, as evidence of the fact, he might point out that numerous large works had long existed simply for the production of mechanical stokers; as also the fact that the most economical power-stations were practically all fitted with mechanical stokers. Of course, there are conditions under which mechanical stokers are not applicable, just as there are conditions under which it is not economical to use compound engines

or condensers; but, for the highest efficiency, there is little doubt that one must use the economies accruing from good mechanical stokers, good compound engines, and good condensing plants; in fact, all the items that go to give the greatest economic effect to a steam-plant, each one adding its own quota of efficiency.

The last sentence in Mr. Longden's paper, namely, "no charge, whatever, for colliery-consumption," is particularly interesting from the fact that some twenty years ago he passed a similar remark with regard to sugar-factory consumption before the Engineering Institute in British Guiana. At the time, fuel was costing about £2 for every ton of sugar made; and, although thought too sanguine at the time, he had the satisfaction of seeing in the course of five years many factories producing the whole of their sugar entirely from sugar-cane waste, and this end was attained by (1) improved furnaces; (2) higher pressures; (3) the prevention of waste of steam from leaky pipes, blowing-off boilers, and condensation in the pipes; (4) the scientific use of the steam for various work in hand; (5) more continuous running of the factory; and (6) an important benefit arising was that the attention necessary for low fuel-consumption acted as a barometer to indicate the efficiency of the engineer and his staff. Having once obtained the highest efficiency with the lowest fuel-consumption, then any increase indicated that something was wrong, and at once pointed out to the engineer and staff that there was some leakage requiring their marked attention. He spoke advisedly, from a connection with plant driven by over 100 boilers, that a low consumption acted not only as a check on the engineer himself, but became his most useful servant in diagnosing the weak spots where his power was leaking away.

Mr. A. H. Stokes (H.M. Inspector of Mines) remarked that there were three points in Mr. Longden's paper to which he would like to allude. In 1892, the output was 283,000 tons, while now it was 560,000 tons, and thus it was, for all practical purposes, doubled. The engines in 1892 must have been standing half their time, and if that half time was taken up in blowing off steam at the boilers, no doubt it accounted for the 7½ per cent. instead of 3 per cent., for the boilers now were probably doing their maximum work. Further, 1s. per ton

was taken as the value of the coal for colliery-consumption; but Mr. Longden did not say how much the public would give for the stuff that he sent into the fire-hole, or whether he could sell it all. If he could not, then it was a question whether, instead of a debit, he ought not to have regarded it as an asset for having consumed it out of the way of the pit-bank. He also desired to call attention to the substitution of 16 second-hand Lancashire boilers for 16 Cornish boilers. He hoped that he should never see a paper recommending the purchase of second-hand wire-ropes, although he had lived to see the purchase of second-hand boilers mentioned in a paper. He could only express the hope that no manager would ever purchase second-hand boilers for a colliery.

Mr. A. Davies (Burton-upon-Trent) said that probably most of the members had read, that at the large generating-station at Deptford, all the mechanical stokers had been abolished, and there had been a considerable saving since hand-firing was adopted. In conversation with the engineer at a large brewery, who was formerly connected with colliery engineering, he asked him why their mechanical stokers were not used. He replied that they were put in to serve a purpose. It was considered possible to use a cheaper coal, and it was quite expected that the men would be able to keep up steam with it. They declared that they could not, and mechanical stokers were duly installed; and, when one of them broke down, the men had to resort to hand-firing with the same coal and there was no difference in the production of steam. They had gradually gone out of use, although kept in order, so that if the men bucked they could be started with other hands to take their places, and they in turn would have to hand-fire the boilers.

Mr. J. Mein (South Normanton) thought that the Institution ought to be proud of having a member who so persistently followed up that particular subject. They might regard Mr. Longden as the apostle of saving in fuel-consumption. It had occasionally been suggested that some of their papers were not free from the taint of advertisement in some form or other, but the readers of Mr. Longden's paper would readily agree that there was no suspicion of advertisement of mechanical stokers in it.

Mr. G. Elmsley Coke (Nottingham) endorsed Mr. Mein's remarks. Mr. Longden had taken up a most important question at an early stage. Great difference in the coal-consumption, even now, occurred at collieries working the same seam under similar conditions.

Mr. J. H. W. Laverick (Nuneaton) asked Mr. Longden whether he could tell the members about the "trellis-firebrick-work" under the boilers. He concluded that the arrangement was intended to deflect the gases.

Mr. G. S. Bragge (Swadlincote) said that the Hydes-and-Bennett flue was brought out in 1872, and it was first adopted at the Blackwell colliery.*

The President (Mr. W. G. Phillips) said that he agreed with what had been remarked by several speakers as to the great obligation under which the members were to Mr. Longden. It used to be a stigma upon colliery managers, although they devoted attention to various matters of varying importance, that they did not trouble much about the coal that they used, mainly, he supposed, because they got it cheap. In comparing the consumption of coal at different collieries, there were many points to be taken into consideration, in order that the comparison might be a just one. Many things had to be done at some collieries which were not necessary at others, and without a knowledge of all the facts, comparisons were apt to be a little misleading. In works where coal was used in the most economical manner and where steam was utilized on the highest scientific principles, mechanical stokers were going out of use. There was, he believed, no industry where steam was so economically used or power so economically raised as in the cotton-spinning mills of Lancashire. Not long ago he was at a mill where they had just put down a new plant: there were new inverted vertical engines of 2,000 horsepower, with boilers 30 feet long and 8¼ feet in diameter, working at a pressure of 200 pounds per square inch, and yet there was only one fireman in the fire-hole using Yorkshire slack, at a cost of 8s. per ton delivered. The coal-consumption was about 1¾ pounds per indicated horsepower. They had the means of detecting any increase in the

* *Transactions of the Midland Counties Institution of Engineers*, 1876, vol. iv., page 22.

consumption, because they could measure the actual work turned out in pounds. He saw at another mill a horizontal engine which had been working for twenty-five years, and the cost of the work done was 0·08d. per indicated horsepower-hour. He visited several other mills, and wherever new plant had been put down he found that the mechanical stoker was discarded in favour of hand-firing. He had been strongly pressed by makers of mechanical stokers to give them a trial, but his own impression was, taking into consideration the cost of providing mechanical stokers and the cost of maintenance, that hand-firing, assuming that it was carefully done, would run mechanical stoking pretty close, if it did not actually beat it. Mr. Stokes had mentioned conditions as to the coal consumed which were certainly not impossible. He (Mr. Phillips) was working under conditions similar to those suggested by Mr. Stokes. He had got a lot of stuff, absolute dust, that had no commercial value, and yet steam was being raised with it. He felt that mechanical stokers had lost a great deal of the esteem that some people used to have for them. He agreed that good results were being got by hand-firing, and that there was not that benefit from machine-firing which had sometimes been represented to the members. He was sure, however, that whatever views the members had upon that point, they would all acknowledge their indebtedness to Mr. Longden for pursuing the subject of "Colliery-consumption," and he moved a cordial vote of thanks to him for his paper.

The resolution was unanimously agreed to.

Mr. W. Price Abell read a paper on "A High-speed Compressor for In-bye Work."

DISCUSSION OF MR. T. W. H. MITCHELL'S "NOTES ON CAPELS FOR WINDING-ROPES."*

Mr. W. Price Abell (Duffield, Derby) said that Mr. Mitchell's paper had caused considerable interest in the Barnsley district, and most of the leading enginewrights had taken up the

* *Trans. Inst. M. E.*, 1905, vol. xxix., page 173; vol. xxx., page 239; and vol. xxxi., page 128.

matter with personal rivalry. The larger collieries had sent caps to be tested, and they had arrived at the unanimous conclusion that a cap, about half the length of the usual riveted cap, with white metal run round the wires, gave the best results, and would break the rope before pulling out. From the results of experiments, it appeared that the mixture of the alloy was an immaterial point, but the wires should not become too hot. Mr. Mitchell's paper had satisfied engineers that the capping could be made of equal strength to the rope, whereas the usual strength had been previously 60 per cent. of the breaking-strain of the rope.

Mr. A. H. STOKES (H.M. Inspector of Mines) said that history repeated itself. The members had heard about the running-in of white metal. He would read them something which was written twenty years and four months ago: "The rope was put through the small end, then wedged the opposite way, and white metal poured in."* There could be no more important subject for discussion at those meetings than the capping of ropes, when they considered that however strong the rope and however good the material, the weak place was the cap, which did not represent more than 50, 60 or 70 per cent. of the breaking-strain of the rope. There was a great fortune awaiting somebody who would invent an arrangement that would hold the rope tighter than the breaking-strain of the rope. What they wanted in a cap was that it should so be made that the tighter the pull the tighter would the cap be. Whether by sliding wedges pulling to tightness or by white metal run in, they would find, if they only turned up the *Transactions*, that these things had all been tried. He hoped that some of the mechanical engineers would devote a little of their mechanical skill to making a cap which would break any winding-rope before the cap gave way.

Mr. G. H. ASHWIN said that ropes, which had been recently capped with white metal and tested in Sheffield, had been broken, and the rope had not drawn. He did not know that it was supposed that white metal was something new when the paper was written; certainly many of the members had heard of this

* "Colliery Winding-ropes and their Attachments to the Cage," by Mr. Pascal M. Chester, *Journal of the British Society of Mining Students*, 1883, vol. vii., page 81; and *Transactions of the Midland Counties Institution of Engineers*, 1885, vol. xiii., page 404.

being used for many years. In some of the samples recently tested, the rope was simply pulled through the cap, the wires untwisted and laid out straight, not being turned back at all, and then the cap filled in with white metal. The discussion originated with reference to locked-coil ropes, but that point seemed to have been lost sight of: the difficulty in the capping of locked-coil ropes being to get the outside wires of the same tension as the inside wires.

Mr. A. H. Stokes (H.M. Inspector of Mines) believed that one of the first caps made with a white-metal core was used at a deep pit in the Midland district. It went all right for a short time, but one day it drew out and left the cage at the bottom.

The President (Mr. W. G. Phillips) believed that all the members realized the importance of the subject. Personally, he had a weakness for having the ropes capped three times a year. The procedure might be regarded by some of them as old-fashioned, but it showed him the inside of the rope for one thing, and that was a matter of some importance. What was, however, of equal importance was that it moved the critical part of the rope from its position at the back side of the pulley and brought it forward. In a deep shaft, where they had a very heavy rope, it was of the utmost importance that the cap should be perfect, but at the same time that would never relieve him of the responsibility under which he would feel for cutting and re-capping the rope. That might be, as he had said, looked upon as an old-fashioned opinion, but in his judgment there was a great deal of virtue in it.

The discussion was then closed.

DISCUSSION OF MR. W. MAURICE'S PAPER ON "A SPARK-ARRESTER FOR LOCOMOTIVES."*

Mr. Henry Wright (Western Australia) wrote that, from experience with locomotive engines, he found that the best plan was to promote a perfect combustion "as far as possible" in the fire-box. To bring this about it is necessary to turn a fire-brick arch in the fire-box, just below the smoke-tubes. If the

* *Trans. Inst. M. E.*, 1905, vol. xxx., page 15.

fuel is fine, a deflector-plate can be used in addition to the fire-brick arch. The difficulty of supplying a sufficiency of air for perfect combustion can be overcome by using Pillatt hollow fire-bars. The air can be admitted at either end of the bars and also taken from the ash-pit. The bars can thus be placed with less spaces than in the ordinary fire-grate, and still the furnace will get a sufficiency of air to bring about a perfect combustion. Mr. Maurice's paper illustrates a device to deal with sparks after leaving the smoke-tubes, and to prevent them from flying up the chimney. It appears to be designed on correct lines in so far that it acts also as a retarder, and no gas or solid matter can go in a straight line from the smoke-tubes to the chimney and thence into the air. He (Mr. Wright) had used an inclined plate in the smoke-box very successfully; and with fuels of low specific gravity, such as those used in Western Australia, the device is very successful in preventing sparking, and also in increasing the evaporation of water per pound of fuel used. The fuels in use in Western Australia are of low calorific value. The native coal contains about 7,000 units of heat per pound, and the native gum-wood about 5,400 units. If used in the ordinary way, the blast of the exhaust in the locomotive would carry a large quantity (in a state of incandescence) up the chimney. For this reason, Mr. James Younger's invention is doubly interesting to those who have to use this fuel, and it seems to provide a means of preventing the escape of sparks by a simple method.

MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD AT THE QUEEN'S HOTEL, LEEDS, JANUARY 23RD, 1906.

MR. T. W. H. MITCHELL, PRESIDENT, IN THE CHAIR.

The minutes of the previous General Meeting were read and confirmed.

The following gentlemen were elected, having been previously nominated:—

MEMBERS –

Mr. HENRY BARTON, Mining Engineer, Central Bank Chambers, Leeds.

Mr. HENRY VERNON HAIGH, Mining Engineer, Lewisham House, Morley, near Leeds.

Mr. GEORGE HOUGHTON, Mechanical Engineer, Old Silkstone Collieries, Dodworth, near Barnsley.

Mr. RICHARD PURDY, Colliery Manager, Tingley Collieries, Wakefield.

Mr. FRANCIS BROWN SINCLAIR, Electrical Engineer, 31, Broomhall Place, Sheffield.

ASSOCIATE MEMBER—

Mr. SINCLAIR WILFRID H. CHAMBERS, Surveyor and Assistant to Colliery Manager, Aldwarke Main Colliery, near Rotherham.

STUDENTS—

Mr. JOHN CHARLESWORTH CRAWSHAW, Mining Student, Dinnington Main Colliery, near Rotherham.

Mr. NORMAN WILKINSON ROUTLEDGE, Mining Student, Colliery House, Garforth, near Leeds.

DISCUSSION OF MR. H. BADDELEY'S PAPER ON "SYSTEMATIC TIMBERING AT EMLEY MOOR COLLIERIES;"* MR. J. T. BEARD'S PAPER ON "THE ACTION, INFLUENCE AND CONTROL OF THE ROOF IN LONGWALL WORKING;"† AND MR. E. W. ROBERTON'S PAPER ON "THE ACTION, INFLUENCE AND CONTROL OF THE ROOF IN LONGWALL WORKING."‡

Mr. W. E. GARFORTH said that, before proceeding to open the discussion of the papers, he wished to explain that some months ago, the Secretary reported that there was a scarcity of papers, whereupon he (Mr. Garforth) suggested that, if each Past-President and member of Council would select one or more papers, which had been read at previous meetings of this and other institutes, with the view of criticizing the opinions of the various writers and at the same time supplementing the original paper by additional experience, it might increase the usefulness of this Institute. This proposal was approved by other members of Council, and hence the present remarks. It was to be expected that the idea would be carried out whenever there was a scarcity of papers which it was hoped would rarely occur. The Council sincerely desired members, especially the younger ones, to make every effort to introduce papers for discussion, for in their preparation useful information had to be collected, ideas had often to be exchanged with older and practical men, and more numerous visits and closer observations had to be undertaken. Theory and practice may, in this way, be combined, and thus tend to give the best judgment.

He (Mr. Garforth) had selected Mr. Baddeley's paper, entitled "Systematic Timbering at Emley Moor Collieries." At the same time, he proposed, at the suggestion of the Secretary, to offer a few remarks, based on practical experience, on the two other papers, read before The North of England Institute of Mining and Mechanical Engineers by Mr. Beard and Mr. Roberton.

Members would recollect that Mr. Baddeley's paper, read in January, 1905, described the straight-line or systematic timber-

* *Trans. Inst. M. E.*, 1905, vol. xxix., page 150.

† *Ibid.*, 1904, vol. xxviii., page 341. ‡ *Ibid.*, 1905, vol. xxix., page 5.

ing carried out under his direction at Emley Moor collieries, during the previous three years, which had been attended with highly satisfactory results. With respect to the Wheatley Lime coal-seam, Mr. Baddeley said that "previous to introducing this systematic [straight-line] method of timbering, the props were set in a rather irregular manner; the roof, being composed of strong bind, came on in heavy weights, breaking the straggling props one by one, and finally came in along the face. Wood chocks were tried with better results; but, as they proved rather expensive, the system of setting two rows of props close together in a straight line was tried. With double the number of props in the row, the roof now breaks off in a straight line, close behind the back row of props, and there is not half the trouble with the face falling in, in fact it is almost a thing of the past, and very few chocks are now set." As regards the New Hards or Silkstone coal-seam, Mr. Baddeley stated that the seam was worked by coal-cutters, but "the roof, being composed of a softer bind, is broken off much more easily; and the seam, being thin, ... is packed solid in the goaf . . . . . only one set of props is left to support the roof . . . . but another row is set, as the holing is done." In the Blocking coal-seam, the straight line of face is carried out as in the New Hard seam, with special arrangements made for setting lids, 12 to 18 inches long, above each prop, with the view of allowing the props to be more easily withdrawn. In conclusion, Mr. Baddeley stated that he "feels sure, if the workmen are taught to set timber in a systematic way, and a strict supervision is kept over them by the officials, that the number of accidents from falls of roof can be most materially reduced." With the opinions expressed by Mr. Baddeley, he (Mr. Garforth) entirely concurred and by way of confirmation he believed that a description of another seam worked on the straight-line system of coal-face would be the best means of opening a discussion on this important question. The drawing (Fig. 1, Plate IV.)* accompanying Mr. Baddeley's paper, shewed the straight line of cut made by the coal-cutter and the straight line of props. In 1902, he (Mr. Garforth) read a paper,† in which the straight line of under-cut was strongly advocated, on the principle

* *Trans. Inst. M. E.*, 1905, vol. xxix., page 152.
† *Ibid.*, 1902, vol. xxiii., page 312.

that the teaching of Nature, as shewn in the cleatage-lines (running through coal-seams, rocks underlying the surface, and the intervening strata) were in straight lines, and he had repeatedly proved that the straight under-cut in the holing produced a straight line of break in the roof, which was most efficiently supported by a straight line of timber. This opinion was based upon many years of experience, and still continued to be confirmed year after year at the collieries with which he was directly connected, and at many others from which he had opportunities of getting reliable information.

He (Mr. Garforth) ventured to think that, in a communication of this character, it was necessary to place before the members the facts, or a description of the details, connected with the natural conditions, artificial means adopted, and results obtained in working a particular seam. If a statement of actual facts was followed by an invitation to any member who wished personally to inspect the seam on the principle that the eye would, under certain conditions, take in more than the ear, it was to be expected that such information would assist those members who were now required, or might in the future be called upon, to work seams of coal lying at great depths. In his (Mr. Garforth's) opinion, one of the principle subjects for discussion, next in importance to that of providing for the greatest safety of the workmen, was one which should treat of the best means to be adopted to minimize the crushing effect of the strata on seams of coal lying at depths of 1,500 feet, 3,000 feet, or more, below the surface, in order to reduce the large percentage of small or low-priced coal, from which disadvantage every colliery working deep mines now suffered.

Holding this opinion, he therefore gave the following statement of the results obtained in working the Diamond seam at the West Riding collieries, together with a few particulars of under-cutting, timbering, and effects produced on the strata immediately overlying the seam:—

Name and Situation of Seam.—**Diamond or Upper Beeston: worked at Normanton, Yorkshire.**

Thickness of Coal.—**3½ feet.**

Inclination.—**Level.**

Depth below Surface.—**1,500 feet.**

Description of Strata.—**Principally argillaceous binds, shales, thin seams of coal, fire-clay and a few strong rocks.**

Temperature.—74° Fahr. at the coal-face, rising to 76° in the return-airways.

Method of Working.—Longwall packgate, with a straight line of face cut by machine, end on or at right angles to the cleatage-lines.

Output.—1,200 tons drawn per day in a single shift, 13 tons per stall, or 6½ tons per man per shift.

Accidents.—No fatal or serious accident has taken place at the coal-face since this seam was opened out 7½ years ago, during which time 1,200,000 tons of coal have been got.

One fatal accident had occurred at the coal-face in the Silkstone seam belonging to the same collieries since 1897, during which time 1,697,929 tons have been got from coal-faces worked by coal-cutters on the straight-line principle.

From Fig. 1 (Plate XIV.), it will be noticed that the main face, in the Diamond seam, is nearly 2,000 feet long, and the two adjoining right and left-hand, or rear faces, are 1,450 feet and 700 feet long respectively. Fig. 2 (Plate XIV.) is a section of the strata immediately overlying the coal. The gateways, 90 to 99 feet apart and 9 feet wide, are usually carried forward for a distance of 600 feet, and they are then cut off by cross-gates. The coal-face advances by successive end-on machine-cuts, 5 to 5½ feet deep. The main face is 3,600 feet distant from the shaft-pillar.

The break in the coal and roof follows the 5½ feet under-cut, and the subsequent and regular breaks are traceable in each gateway and waste as shewn in the section (Fig. 2, Plate XIV.) which has been prepared from actual measurements. The roof-breaks are almost vertical (at an angle of 85 degrees), and extend up to the "four-feet stone" in certain districts, and to the "seven-feet stone" in other parts of the mine. They occur with interesting regularity, from the coal-face down the gateways, where they are seen at intervals of 5 to 5½ feet, corresponding to the under-cuts made by the machines. On reference to Fig. 2 (Plate XIV.), it will be noticed that in addition to the vertical breaks, called for the purpose of distinction "minor breaks," there are other or "major breaks," inclined at an angle of 45 degrees and separated one from the other by distances of 35 to 40 feet. These latter breaks extend up to the seven-feet ironstone-parting or to the "ten-feet stone." They are independent of the machine-breaks, and are found to occur in the strata or ripping of the gateways, and sometimes between the vertical or minor breaks as the width of the span increases. The major breaks, occurring at the distances mentioned, may be said to be

formed on the principle proved in beams and girders, say, that the strength is in direct proportion to the depth or thickness of strata in question, and inversely as the span or distance between the supports, in this case, say, the coal-face and the consolidated dirt-pack. To ascertain whether the line of break continued, and in order to measure the extent of the settlement and the cavities between each stratum, a pit, ABDC, was driven to the ten-feet stone, at the side of the major break, AB (Fig. 2, Plate XIV.). The measurement of the vertical depth of the strata, after the break and cavities had appeared, was 4 feet 3 inches instead of 4 feet, 7 feet 5 inches instead of 7 feet, and 10 feet 6 inches instead of 10 feet.

With respect to the method of timbering (Fig. 3, Plate XIV.), the props measure 3½ feet to 4 feet 4 inches in length (according to the undulating nature of the floor) and are 5½ inches in diameter. They are set in accordance with the Home Office and Special Rules, which specify that the distance between props shall not exceed 4½ feet; and they are set 4 feet from the face. A bank-bar is set on every alternate prop, and the face-end is let into a pocket-hole made in the upper part of the coal. These bars are made by cutting props (4 feet 8 inches long by 6 inches diameter) in half, and flattening the ends so as to facilitate the setting.

After the machine has undercut the coal to a depth of 5½ feet, the machine-men set straggling props under the face-end of the bank-bars and sprag the coal with wedges placed 4½ feet apart, in the undercut. Two rows of face-props are left standing, the third row being drawn by the stallman as the work of filling the coal proceeds. Chocks, formed of pieces of oak, 22 inches long and 6 inches square, are set, 24 feet apart, along the face in duplicate, and are moved forward alternately; and one chock is also maintained in each pack-hole, these latter being moved forward by the rippers. All timber is withdrawn, except those props which the deputy decides are unsafe to draw. As the work of filling the coal proceeds from the end of the buttock, a temporary prop is fixed until the permanent timber can be set in accordance with the Special Rules. The coal-face has never "fallen in," consequently there has been no necessity to "bord out," due to the weighting or breaking-down of the roof during the 7½ years that the Diamond seam has been

worked by machine with a straight line of timbering. The cost of the face-timber amounts to only 1½d. per ton, due to the special method of working described.

Four feet of space is left, on each side of the gateway, for the ripping-dirt, 3 to 4 feet thick; and the miners make up 11 feet additional on each side, or together equal to 15 feet of gate-pack. Two middle packs, not less than 9 feet wide, are made with the machine-cuttings and bottom-dirt, leaving wastes 24 feet wide. Measurements have been taken to shew the extent of the gradual settlement of the roof on the dirt-packs, as follows:—At the coal-face, the height of the roof is 4 feet 2 inches; at 1 chain from the face, the height of the roof is 3 feet; at 2 chains, 2 feet 8 inches; at 3 chains, 2 feet 3 inches; at 4 chains, 2 feet 2 inches; and at 14 chains, 1 foot 9 inches. A photograph, taken to illustrate the subsidence, shews six distinct settlements or steps in the roof.

No timber is required in the gateways leading from the crossgate to the coal-face, owing to the artificial breaks crossing the lines of cleatage, thus reducing the number of breaks, and allowing the strata to settle much more quickly and in more solid blocks. The two lines of props, which are left standing until after the ripping is finished, and the packs built are generally broken by the settlement of the roof. Telescopic props have been used with advantage.

In the south and east side districts, an inspection has been made in twenty-nine gateways (9 feet wide and 7 feet high, when first ripped) or, say, a total length of 1½ miles, in which there is neither prop, nor bar, nor stretcher to support the roof. But in the crossgates (10 feet wide and 7 feet high), which are carried forward at an angle of 45 degrees from the main haulage-road, a considerable quantity of timber and steel bars is required. This extra quantity is required, owing to the crossgate-breaks being crossed at an angle by the coal-face breaks.

The plan (Fig. 1, Plate XIV.) shews that the two rear faces are a considerable distance behind the 2,000 feet or main face. Where the south-east face has been worked alongside the old goaf, breaks have been produced of greater or less magnitude according to the distance from the old goaf. These breaks are shewn in Fig. 4 (Plate XIV.) by straight lines, which run parallel with the gateway and extend over a distance of 50 to

60 feet: they may be looked upon as crushed coal, especially as the strata have been further affected by the induced straight-line fractures, which give this small area a kind of chess-board pattern, the size of the squares gradually increasing as the distances from the goaf increase. After the distance mentioned, the effect arising from the goaf does not detrimentally affect the remaining portion of the coal-face.

Having described some of the natural conditions of the coal-seam and strata and the effects and details connected with the under-cutting, the induced fractures in coal and roof, the timbering and packing, he (Mr. Garforth) would briefly summarize some of the advantages obtained in working the coal by the method described.

With respect to the under-cut, the experience of the past 7½ years in this seam and 12 years and 8 years respectively in two other seams (the latter having an unstratified rotten clod-roof), had proved that the straight under-cut could be maintained. The setting of timber must, however, be only looked upon as dealing with the effect, the cause of the timber being placed in a straight or in an irregular line is due to the direction and character of the under-cutting. A straight cut produced a straight break, and a sinuous or irregular cut an irregular break. The placing of timber in crooked lines with no two settings alike, even under normal conditions, could not be called systematic, and perhaps a better name would be "the regular spacing of timber." Having regard to improved methods for winning coal, he (Mr. Garforth) thought that "systematic timbering" should be understood to mean doing the same work day by day and month by month in almost exactly the same way. The foregoing facts shewed that the system, being carried out in straight lines with props placed according to a prescribed distance, had resulted in greater safety to workmen, better quality of coal, quicker and more regular settlement of the surface, with consequent less injury to property, intervening coal-seams, etc. The use of mechanical conveyors, the use of sledges on coal-cutters to dispense with wheels and rails, and other contemplated improvements, all point to the coal-face being worked and to the timber being placed in straight lines.

He (Mr. Garforth) formerly considered that the so-called straight face in the Old Silkstone seam, at the same collieries,

holed by the hand-pick and gauged by an instrument, was straight; but, with the experience gained by machine undercutting, during the past 13 years, the difference and defects between the two systems are most noticeable. Amongst other reasons, and to shew the effect of superincumbent weight, it may be mentioned that in 1881 a narrow or straight road was driven in advance of the coal-face and numerous breaks were noticed; and their character shewed that the strata, above the advancing irregular line of coal-face, had broken over the solid. A similar narrow road had lately been driven in advance of the straight-line coal-face without such breaks being perceived. From these facts it is argued that, whilst in the former case the overlying strata broke irregularly, in the latter instance the straight line of face produced a straight line of weak resistance, which allowed the strata regularly or systematically to fall back in the direction of the goaf. In the case of flat seams, the action may be compared to something like the leaves of a book falling back on each other when the binding overhangs.

He (Mr. Garforth) might remark that what occurred in the overlying strata after the excavation in the coal-seam had been made, when a certain area of goaf had been exposed, and the settlement of the roof and other strata had taken place, had been a constant source of speculation to the mining engineer. But now that the coal was being got in such a manner that the settlement of the roof occurred with regularity and parallelism there seemed to be a better prospect of satisfying this curiosity, as it was possible in many cases to define the rock-movement. With the knowledge of what had already been done by producing a straight break by means of a straight under-cut, or an irregular or sinuous break by an irregular cut, the mining engineer would now be able to induce a more regular settlement of the strata on the goaf, and thereby relieve the coal-face from an overhanging weight in a way that had only been realized within the last few years. This would be another important step in the direction of reducing the percentage of small or low-priced coal in working deep mines.

Although there were many interesting details which might be mentioned in connection with the effects produced on the roof, etc., yet as these remarks on Mr. Baddeley's paper were much longer than intended, he (Mr. Garforth) could only briefly refer to

the two papers read by Mr. Beard and Mr. Roberton. From the drawings accompanying Mr. Beard's paper,* it would be noticed that he suggested that the coal-face should be worked in curved lines. This system of work was directly opposed to the method referred to in the foregoing remarks, and to Mr. Baddeley's suggestions, both advocating the straight line of cut. He (Mr. Garforth) made the following remarks in a previous communication, from which he ventured to quote now, as the experience of many years had since confirmed the opinion then expressed, namely:—If the coal-face be worked on a curved line "there are serious disadvantages, including amongst others:—(1) Under-cutting the back of the holing in an irregular line; and, when an extra depth of holing is necessary to ensure the excavated coal breaking from the solid portion, cutting or slabbing part of the solid face into small pieces to permit of shoulder-room for the workman. The projections at the back of the holing act as struts almost as effectively as the sprags in front of the coal-face, especially when assisted by the undermined coal adhering to the roof and the back of the solid coal. The projecting portions are consequently exposed to an excess of crushing-weight, ... and the coal (being usually softer than the roof and floor) suffers by such association. (2) Undermining one part of the coal-face at a period of time different from the adjoining portion, consequently an additional weight is thrown on the remaining portion of the holing dirt; . . . a greater percentage of low-priced coal is produced."† "If it be correct to work coal by following straight lines, either on the principle of (*a*) plumb end, (*b*) bord, or (*c*) half end and half bord, then the coal-face cannot, for the reasons given, be advantageously worked at constantly varying curves and angles. When the coal is worked end on, it may be said to have its maximum strength to resist pressure, and allows the deepest excavation to be made before the coal falls, usually in large pieces and with a cubical fracture, even in the smaller pieces. On the other hand, the coal most readily falls when worked bord-way, or when the lines of cleatage run parallel with the cutting, in which case friable, slabby, and an increased percentage of fine-coal results."‡

* *Trans. Inst. M. E.*, 1904, vol. xxviii., Plate IV., page 346.

† *Ibid.*, 1902, vol. xxiii., page 324. ‡ *Ibid.*, page 326.

As Mr. Beard was not present to explain certain matters not mentioned in his paper respecting the depth of the seam from the surface, the nature of the strata, how the getting price was regulated with the men working alternately end on or bord on; how the coal-face was maintained in curved lines, especially when men did not regularly attend work; and whether the roof was

FIG. 1.—UNDERCUT FACE OF COAL.

broken at the loose ends, besides other matters, he (Mr. Garforth) thought it undesirable to criticize the paper further. There might be special circumstances, and the profitable working of the colliery might not be dependent on obtaining a high percentage of large or high-priced coal, such as was required at the collieries of the Yorkshire district.

Some of the foregoing remarks equally applied to Mr. Roberton's paper, but it might be further pointed out that, about 1870, the Silkstone face, to which reference had been made, was driven with a step face as shewn in Mr. Roberton's drawing.*

* *Trans. Inst. M. E.*, 1905, vol. xxix., page 10, Plate I.

Owing to the corners of the steps being crushed by the superincumbent weight and the consequent loss by the larger percentage of small coal, the method was abandoned more than 30 years ago. He (Mr. Garforth) preferred not to criticize further, but he would be guided by the subsequent discussion, as there were certain remarks which might be construed to mean that Mr. Roberton preferred a straight line of face.

FIG. 2.—MAIN GATEWAY, WITH BLACKETT CONVEYOR.

In conclusion, he (Mr. Garforth) wished to explain that recently he had carried out further experiments, commenced many years ago, with the view of seeing, on a large-sized model, how lines of fracture might be produced or induced by removing supports in straight and also in irregular lines, similar to those herein described, but they were not yet completed.

Mr. H. Baddeley said that it was now more than twelve months since he read his remarks on "Systematic Timbering at Emley Moor Collieries," which were intended to be a supplement to a paper that had previously been read on this subject, rather than a separate paper. Seeing that there was so little in it to discuss, he thought that a few remarks on the system of timbering in a conveyor-face might interest members who had not already

Fig. 3.—Main Gateway.

seen a conveyor at work, and more especially as several members had remarked that they could not see how the roof could be kept up, as there was too great a width of roof on the timbering. This might be so, but the rate at which the face travelled must not be forgotten, say, 20 to 27 feet per week. In his (Mr. Baddeley's) opinion, this, along with the quick changing of the timber, and the straight line of face, was to a great extent the secret of this particular kind of work. He did not wish to infer that conveyors could be worked with almost any kind of roof, but

he did think that with a roof of moderate strength they could be worked to great advantage in thin seams. Fig. 1 shewed the face clear: the face of coal having been filled away since last the conveyor was shunted or moved forward. The face of the coal had again been under-cut, two fresh rows of props set, and the Sylvester prop-drawer got ready for moving the conveyor forward. The row of props in front of the conveyor was drawn out, and the conveyor pulled over to the next row: the props in this particular row were only set to maintain the roof, while the con-

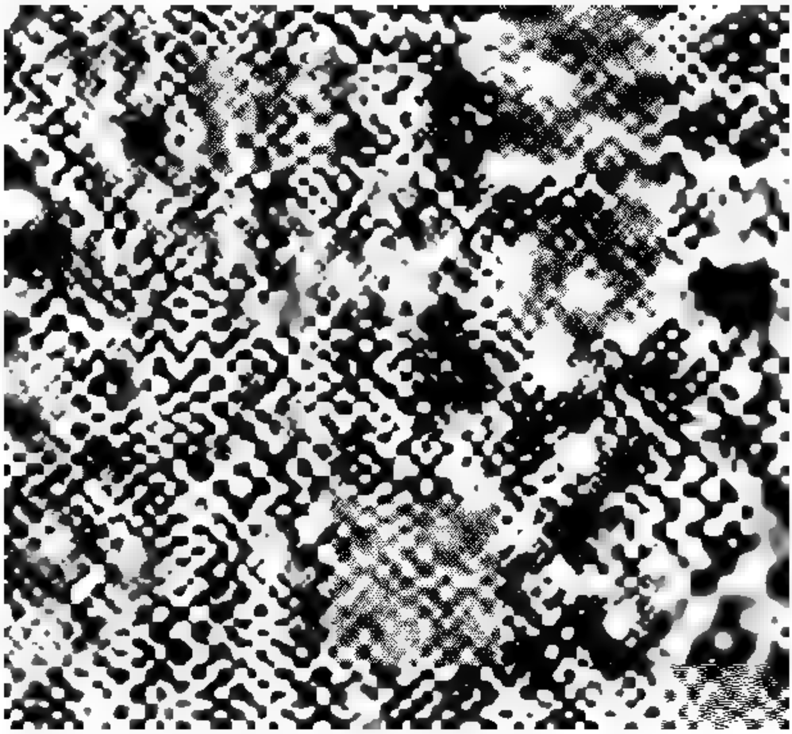

FIG. 4.—MAIN GATEWAY, WITH COAL-CUTTER.

veyor was being moved forward. The props were set about 5 feet apart from prop to prop along the row, and another line of props was set behind the conveyor which was now moved half the distance: this row was only set where the roof was not good. The line of props in front of the conveyor was now taken out, and the conveyor was moved forward to the face-row of props, which were in this case set 3 feet apart from prop to prop.

Another similar row was set behind the conveyor, so that these two rows of props were only 2 feet apart. Wood chocks, 2 feet square and 15 feet apart, were set close behind the conveyor. All back props and chocks were then drawn out. As stated above, the distance between each row of props was 2 feet, but the distance between the coal-face and the front row of props was 4 feet, leaving room for the coal-cutter to travel along the face. When, however, the machine had made its under-cut, two rows of props were set, one close to the coal-face and another

Fig. 5.—Blackett Conveyor.

was set between that and the one in front of the conveyor (Fig. 1), so that the rows of props, as stated above, were only 2 feet apart, except during the time when the machine was cutting along the face. The main gateway (Fig. 2), into which the conveyor delivered the coal, was 9 feet wide and 6 feet high, and set with steel girders, 3 feet apart (Figs. 3 and 4). No ripping was done in the top stone, but the bottom stone was taken up, 3½ feet thick. The main gate-road was driven in advance of the coal-face by a Champion heading-machine. Two conveyors (Fig. 5) were now delivering coal into this main gate-

road; and one face was from 25 to 30 feet in advance of the other. This was a great improvement on the method of working with one conveyor, in which case the main gate-road had one pack-wall and one post side, causing the roof to cut off along one side; whereas, with two conveyors, the whole of the coal was taken out, and the main gate-road settled in a body on to the pack-walls, and, there being only one main gate-road to make for both conveyors, a considerable saving was effected.

In conclusion, he wished to thank Mr. A. Crowther for showing the views on the screen and Prof. G. R. Thompson for taking the photographs that had been shewn.

The President (Mr. T. W. H. Mitchell) observed that the members were greatly indebted to Mr. Garforth for the excellent manner in which he had opened the discussion; and he had set a heavy task before the other members of the Council. A few years ago, he (Mr. Mitchell) had occasion to take particulars of the cracks in the goaf-road and level-road, together with the effect on the surface; and he found, owing to the regular way in which the face was kept going, that an even and very regular subsidence was produced.

Mr. P. C. Greaves said that recently one feature had come before his notice, and had given trouble. One particular face was being worked slowly, and caused constant trouble from falls. They now worked better time, worked the face faster, and the result was that the breaks became more regular, and they had fewer falls; but when they worked five days per week, weeks elapsed without a fall in a gate-way or at the face. After each holiday, trouble was sure to ensue within about a fortnight, and it seemed to him that one of the most important features was that the pit must be kept working full time, which, in the present state of trade, was impossible. A number of chocks were set on that particular face; but they found that they were not so good as props, and now nothing but props were set. Wherever systematic timbering was used, it must be carried out to the fullest extent, and no small point must be missed. As an example, in another pit, chocks were set 15 feet apart: owing to someone's neglect, there was a shortage of chocks and they had to be set 24 feet apart, and in consequence a heavy break took place.

Mr. J. R. R. Wilson said that it was to be inferred from previous remarks that the breaks always took place in a direction towards the goaf. If the breaks continued in that direction to the surface, how was it that they often heard of claims for damages in respect of property on the solid side of coal-faces? There was always what they called "draw," and evidence of a certain pull and subsidence beyond the line of face. This line of subsidence, and perhaps of fracture, was very regular. He had frequently noticed breaks in a machine-cut face as regular as those that Mr. Garforth had described, leaning, not into the goaf, but over the face. They were sometimes described to him as slips: they were slips in appearance, both sides being perfectly smooth. He had only seen them where the faces were moving very slowly, and so the roof had plenty of time to subside in its normal way, that was, with the line of fracture leaning over the solid. The usual break that they got with faces moving quickly, as Mr. Garforth had described, was, of course, simply an ordinary fracture of the roof, which, unable to support itself, fell into the cavity. Following this, they had the whole pressure of the strata sliding down, which would produce the effect of breaks leaning over the solid.

Mr. C. C. Ellison said that it would be interesting to know why the men wanted extra pay for using iron girders, and what had been the effect of not adopting steel props.

Mr. H. Bonser said that in Derbyshire, 20 years ago, in working the Deep soft seam, a system, such as that advocated in Mr. Beard's paper, was adopted with a view of getting round coal; and he asked whether the writers of the papers had not more the idea of producing round coal than anything else, in their minds, as was the case in Derbyshire, where the long horn system was worked with good results as regards the production of round coal.

Mr. S. Field wrote that he had read Mr. Beard's paper with considerable interest, and whilst he was unable to agree with it entirely, he could endorse many of the opinions expressed. The division of the superincumbent strata into two separate masses was substantially correct, although in all probability the cantilever-action of the overweight played a more important part in determining the breakage of the underweight and of the coal

than Mr. Beard thought. He (Mr. Field) understood by under-weight, the strata upwards from the coal to a stratum of such physical character as to be able to bridge over a considerable area. Mr. Beard's remarks on the influence of the roof's action were clear and to the point, and he (Mr. Field) entirely agreed with them. He did not agree with Mr. Beard's idea of the control of roof-pressure in longwall-workings. He had thought, until reading these papers on the control of roof-pressure in longwall-workings, that the fallacy of step-working, or modifications of step-working, as aids to roof-control, had been exposed many years ago, and that true longwall-work consisted in having as long a length of straight-line face open as circumstances would permit. It was true that few collieries had great lengths of face in a straight line, but the irregularities were not associated with any idea of controlling the roof-pressure. Mr. Beard evidently thought that, by an eccentricity of the face-line, the roof-pressure could be controlled. Now when it was considered that the general line of face determined the induced break in the overlying-strata, the fallacy of this idea was easily appreciated. Any obstruction or deviation from the straight line imposed on that portion an excessive weight and produced what he (Mr. Field) might term a "gobbing-weight break," that was, an induced break, which ought, in the proper order of procedure, to have been made on the back gobbing some time before. In speaking of the influence of the roof-action, Mr. Beard stated that "the influence of the action of the roof may be disastrous when, owing to a lack of uniformity in the line of the working-face, a secondary movement is set up in the roof, or the travelling weight is started off in a wrong direction, throwing an irresistible weight or pressure on the road-packs, or on some portion of the coal-face;"* and then he proposed to control the roof-pressure by the lack of uniformity which he had previously condemned. The only way in which the roof of a coal-seam could be controlled by natural means was by leaving pillars of coal, as in pillar-and-stall work, where the size of the pillars was regulated by the strength of the roof, floor and coal, and in this way no induced breaks were produced. In longwall work, the control must be effected by artificial means, by pack-walls and timber, and the interposition of an irregularity in the face-line to control the roof-pressure acted on that portion in a

* *Trans. Inst. M. E.*, 1904, vol. xxviii., page 343.

similar manner to what would occur if the pillars of pillar-and-stall work were left far too small: the roof would be badly broken, and the coal crushed. The error of this system of roof-control was obvious, when it was considered that a length of roof, which had been badly broken in the attempt to control the roof-pressure, had to be controlled by the very same means that would have been used had it been preserved in its best state under straight-line conditions: that was, by packs and timber. The combination of straight-line face, systematic timbering and packing and the withdrawal of all back timber, was productive of the best results in longwall work, so far as the condition of the roof, the coal, the coal-getting, and the maintenance of the roadways were concerned. He (Mr. Field) thought that any colliery working on these lines would experience no difficulty in keeping the cost down to the lowest level.

Mr. W. Walker, in proposing a vote of thanks to Mr. Garforth for what was practically another paper, said that he was convinced from the facts and figures given, of the advantages of working on a straight-face system such as that described. He felt this very forcibly when he looked over the number (71) of fatal accidents from falls that had occurred during the last year in the Yorkshire mines-inspection district, whereas Mr. Garforth had worked over 1¼ million tons without a fatal accident from this cause.

The vote was agreed to.

Mr. W. E. Garforth said that, for many years at the colliery with which he was connected, levels had been taken before and after the coal-face advanced, so that it might be known from half-year to half-year what subsidence was taking place, and he could confirm what Mr. Wilson had said. Sometimes, owing to local circumstances, the weight had broken over and affected property 300 feet away. An instance occurred some time ago, where the effect was noticed 500 feet away, but there were attendant circumstances which he could not there describe.

The discussion was adjourned.

Mr. Ellis Barraclough's "Practical Notes on Winding-ropes and Capels" were read as follows:—

PRACTICAL NOTES ON WINDING-ROPES AND CAPELS.

By ELLIS BARRACLOUGH.

As the subject of winding-ropes and capels has been recently brought very prominently to the notice of the members in the *Transactions*, and as a Commission has been appointed by the Government of the Transvaal to enquire into the subject of "the safety of persons lowered or raised in shafts" for which evidence is being collected in his mines-inspection district by Mr. W. Walker, H.M. inspector of mines, the writer has thought that a few notes on the subject relative to the treatment and care of ropes, etc., at the colliery with which he is connected would not be out of place, and might be of some interest to his fellow-members. He does not, however, anticipate being able to bring to their notice any novel or special features, the methods followed being those used in general practice. His object in writing this paper is to lay before the members his own personal experience, and to elicit the opinions and experiences of his fellow-members for their mutual benefit.

Winding-ropes.—The only varieties of ropes in use at Ackton Hall colliery are (*a*) Lang lay and (*b*) locked coil. The former had been, until recently, the only ones used; they had been generally satisfactory, and had done their work well, being taken off at the end of periods averaging about three years. The performances of several winding-ropes, typical of the whole, are recorded in Table I.

TABLE I.—DIMENSIONS, DURATION OF USE, AND COST OF LANG LAY WINDING-ROPES.

No. of Rope.	Description of Rope.	Dimensions of Rope.			Top-side Rope.	Time in Use.	Cost of Rope per Ton of Coal raised.
		Length.	Diameter.	Circumference.			
		Feet.	Inches.	Inches.		Years.	Pence
1	Best plough-steel... ...	1,275	...	4	Yes	$2\frac{1}{2}$	0·073
2	Improved special steel ...	1,530	$1\frac{1}{2}$	$4\frac{3}{4}$	Yes	3	0·061
3	Best plough-steel... ...	2,160	...	$5\frac{1}{4}$	Yes	4	0·137

Treatment.—When sent from the makers, the ropes are usually already well covered with oil, and this should be sufficient for some time. At the end of six or nine months, more oil is applied to all visible portions, and a quantity allowed to run into and through the coils; and this is found to keep them in good order until required for use. When received from the makers, the ropes are stored in a dry place, being placed on a platform 3 or 4 feet above the ground, covered with tarpaulin, and inspected from time to time.

When put into use, the ropes are examined in the ordinary way each day, being wound at a slow speed up or down the shaft, while the examiner carefully looks for any broken wires or other defects. Once a week, the ropes are well oiled, and passed carefully through the hands of the examiner: any broken wires being at once detected by the hand or the eye.

A length of 30 or 40 feet of the rope nearest to the capel is periodically cleaned, scraped, and again carefully examined, as this portion is found to be the most difficult to keep well lubricated owing to the dust, etc., absorbing the oil and rendering it dry; and a good dressing of oil is afterwards applied.

The daily examination of the ropes is usually made at luncheon-time, the normal working-load being on the cage for the purpose. The lubricant used is either Russian or vacuum oil, of about the same consistency as treacle. This dressing is found to be still efficient at the end of a week's time, and materially assists in preventing corrosion of the wires, and in reducing the friction between the ropes and the pulleys or drums. The dressing used does not prevent the examination of the rope. The shafts being dry, no metallic covering is used on the ropes.

The internal examination of a rope is not easily possible, but some estimate of the state of the interior may be formed when recapping takes place. This is done at the end of the first twelve months in the life of the rope, at the end of each six months in the second year, and of each three months in the third year. Thus the internal state of the rope may be seen at least six times during its working life, at the point which is generally looked upon as being most susceptible to corrosion, namely, near the capel. At each recapping, a portion of the rope is cut off, varying in length from 6 to 30 feet according to circumstances, and very little corrosion is found as a rule.

No springs or other automatic contrivances are used, but the ropes are adjusted carefully to their proper length, so as to avoid or to reduce to a minimum the sudden jerks, which are ruinous to the "temper" of a rope and considerably shorten its life.

It is generally the writer's custom when a new rope is put on, to order another into stock to replace it, although this is not always done until some time, perhaps twelve months, has elapsed. A rope will, therefore, be stored for, say, two years before being used; but, if well looked after, it does not suffer any evil effects during that period, and is always available in case of necessity or urgency.

Much of the foregoing may be considered as insignificant detail; but, in the writer's opinion, it is the perfection of such detail that makes the difference between good and bad results.

Cores.—Ropes are generally made with either wire-cores or hemp-cores, the former being most commonly used for deep mines with heavy loads: this class of rope having less liability to internal corrosion. As there is little or no difference of cost between wire-cores and hemp-cores in winding-ropes, nothing can be gained financially by the use of ropes with either class of core. When, however, the wire-core of a winding-rope breaks at one or more places (which, in the writer's opinion, occurs far more frequently than is generally imagined), it at once ceases to do any useful work in the way of lifting the load, and becomes, instead, a dead weight upon the rope. In the writer's opinion, it is also a considerable factor in reducing the strength of the outer strands, as the rope in passing over the pulley loses its symmetry at the points where the core is broken, and receives a series of shocks due to variations in its rigidity. The writer is, therefore, inclined to think that, where this class of rope is used, success or otherwise is dependent largely upon the amount of twist given to the core in the making of the rope. The twist should be sufficient to allow the core to stretch in the same ratio as the outer strands, otherwise it will either break or draw itself up the interior of the rope. The stretching of a rope will also vary somewhat with local conditions, which, in many instances, are unknown to the makers.

The writer, therefore, has come to the conclusion that, all

things considered, the use of wire-cores is not advantageous. The following is a brief record of experiences with this class of rope, which has led to the abovementioned conclusions.

The first experiences were with winding-ropes. In several instances, it had been noticed, when new ropes were put to work, that the core, not stretching with the outer strands, took the weight for the time being; and, the strands being slack, they bulged out at some point shewing the interior of the rope and forming an enlarged place upon it (Fig. 1, Plate XV.). More than one bulge had formed, on some ropes, at various points between the drum and the capel, and in one instance a bulge actually occurred inside the drum, between the laggings and the drum-shaft. In few instances were bulges interfered with, as they appeared to right themselves, and consequently the ropes were allowed to run their normal course. A special examination, made after a rope had been finally taken off, revealed a broken core where a bulge had formed in the first instance; but, so far as could be detected by the eye, no difference in the wear of the rope had taken place at the point where a fracture of the core had occurred. What might have been the result had the rope been sent to be tested to its breaking-limit the writer does not care to suggest, but he believes that the margin of safety would have been much smaller than he would have liked.

In another case, the core broke at a point 35 feet from the capel, and drew apart for a distance of 6 or 8 inches, gradually decreasing in thickness towards the point of fracture (Fig. 2, Plate XV.). This defect was discovered by the rope-examiner about 10·30 a.m. while making his usual examination. The pit ceased winding at 12 noon on that day, and the men were drawn out on the other rope. It was decided to cut off the portion of rope beyond the point abovementioned, and recapel it; this was done, and the rope ran its normal course without any further occurrences of a similar character.

The second experiences were in the tail or balance-ropes, suspended from the cages in a shaft, 1,740 feet deep. When the first of these ropes was being prepared for use, it was found to be 16 feet too short to connect to the cages, and 30 feet shorter than the length ordered. This difficulty was overcome by attaching a chain at each end under the cages; and, after a time, one of the chains was removed, as the rope had stretched. The

fact of the rope being 30 feet shorter than the ordered length, occasioned some surprise to the makers when that fact was pointed out to them. The remarkable feature in regard to this rope was that the core at the point of the rope, which at the end of each second wind came into contact with the sump-pulley, commenced to push through the strands, thus forming enlarged portions, which had to be cut out, and in the course of time this operation became a weekly necessity. The rope was taken off and the ends attached to the reverse cages, in the hope that by running it in the opposite direction this defect might be remedied. However, the core pushed itself out at the other end of the rope in the same position, in just the same way as before, 120 and 180 feet respectively being taken out. [The two pieces of core shown at the meeting were taken out of this rope, and illustrate how the core-wires cluster together and work through the outer strands.]

The second balance-rope, and that now in use, was capeled in the ordinary way, and after two days' work had stretched to some extent, so that it became necessary to shorten and recapel it. The end of the rope was cut off and examined, and it was then found that the wire-core had been withdrawn, up the centre of the capel, for a length of 9¾ inches (Fig. 3, Plate XV.). It is possible, and to be presumed, that this process would have continued; and, if so, the result might have been serious, as, the heart of the rope being drawn out, there would have been nothing to prevent the swell upon it from collapsing to a greater or less extent, and the rope from being drawn out of the capel.

The writer ventures the suggestion that the foregoing remarks may offer some explanation of the, hitherto, inexplicable failure of winding-ropes in times past.

Capels.—The variety of capel in use at Ackton Hall colliery is that commonly adopted, namely, two halves, securely connected by four collars, tightly driven on by hammers. The capels are made at the colliery of best cold-blast Farnley iron, and shaped on the anvil to the required size. The four edges are then planed, in a machine, in order to ensure their parallelism, and the pin-holes are drilled. A spare capel, for each of the pits, is kept in stock. A sketch of the capel is appended (Figs.

4 and 5, Plate XV.). The pin attaching the capel to the cage is 2 inches in diameter.

The method of capping is somewhat as follows:—The rope being cut to the required length, the hoops or collars are passed on to it in their proper order. A binding of soft-drawn iron-wire (No. 15 Birmingham wire-gauge) is then put on for a length of $7\frac{1}{2}$ inches, commencing at a point about 2 feet 6 inches from the end of the rope. A second binding is then wound over the former one, but it is only carried up a length of 5 inches, and a third wrapping, on the top of the second one, is carried up a length of $3\frac{1}{2}$ inches. These lappings form a more or less conical plug, over which the outermost of the rope-wires are turned backward for a length of 2 feet 6 inches, and hammered or pressed into position. The other layers of wires are treated in the same way, each successive layer being cut off somewhat shorter than the preceding one, so as to gradually increase the size of the plug from the top to the bottom. The whole end is then again carefully wrapped with wire as before and as tightly as possible. During this final wrapping, a screw-clamp is used, which is first put on about 3 inches from the end, and the wires pressed together as tightly as possible (Figs. 7 and 8, Plate XV.). The wrapping is carried up to the clamp, which is then released, tightened again about 3 or 4 inches further on, and the process repeated up to the top. The wire-wrapping machine is shown in Figs. 9 and 10 (Plate XV.). The nut, A, is used to regulate the tension of the binding-wire.

The rope is now ready for insertion in the capel; the two halves being laid together, a pin, fitting the holes, is inserted so as to maintain them in their proper relative positions. This is a most important point, as failure in this respect will probably result in the rope drawing from the capel: for, the strain coming upon one half, B, only of the capel to commence with, will cause the hoops, G, to become dislocated (to some extent) before the other half, A, takes up its load. A somewhat exaggerated view of this dislocation is shewn in Fig. 6 (Plate XV.) in order to illustrate the effect more clearly; and the obvious way to prevent this from happening is to have the pin-holes carefully drilled, and the pin made a dead fit. During the process of capeling, a spare pin is used for insertion in the pin-holes, as the permanent pin, if used for the purpose, might sustain some damage

due to the hammering necessary to force on the collars. The collars are now driven tightly down upon the capel, firmly gripping it; and it has been found that, except in two instances, no movement of the rope had taken place. The first of these was caused by neglect of the precaution described to ensure an equal strain being taken by both halves of the capel: the rope ran three weeks and then drew $1\frac{1}{2}$ inches; it was then recapeled, and ran without further trouble for the remainder of the normal term. In the second instance, the rope drew about $1\frac{1}{2}$ inches on the day after the capel had been put on. This was found to be due to the swell on the rope not being large enough: the rope was recapeled, more wire being used to increase the size of the swell, and it ran without further trouble until recapeled in the ordinary course.

Another important point is the tendency of the wrapping wires to squeeze in between the two halves of the capel, when the collars are driven home, as shown on Fig. 11 (Plate XV.): this may be avoided to a great extent by wrapping the rope very tightly, and rounding off the edges of the half-capels so as to give them a lead. If, however, it occurs, the wrapping should be undone, any projecting strand-wires cut out, and the whole rewrapped.

When a rope is recapeled, the capel taken off is carefully examined by the smith, and if any defects are discovered, it is discarded. If quite sound it is annealed, dressed up, and put into stock for further use.

Locked-coil Ropes.—Two locked-coil ropes have been in use for the past twelve months, and have so far given every satisfaction. They were put on in place of the ordinary type of rope, because the drum was not sufficiently wide to take the ropes without overlapping. The locked-coil ropes being smaller in diameter for the same strength, this objectionable feature of overlapping was obviated. They run very steadily in the shaft, and, once they have been adjusted, do not stretch further, giving little trouble afterwards. They are capeled in a manner similar to the ordinary type of rope, a method which has been found so far satisfactory, and the capels have not shown any signs of drawing.

A plate (Figs. 12 and 13, Plate XV.) is used to connect the safety-hook to the bull-chains. This plate, 13 inches square and 2 inches thick, was made at the colliery of best cold-blast Farnley iron. The holes, 1⅜ inches in diameter, are drilled to an accurate fit with the shackle-pins. These plates wear for a considerable time; but, eventually, owing to the constant lifting of the cages, the holes become slotted to some extent. A new plate is then substituted, and the one taken off is carefully examined for any possible flaw. If still quite sound it is annealed, and the holes redrilled of a slightly larger diameter so as to include the slotted portion; new pins of slightly larger diameter are fitted, and the whole put into stock for further use. A good margin of metal is provided for in the first instance, so that the strength of the plate is always ample for the work which it has to do.

Tests.—Table II. contains the result of a test made with a winding-rope capeled in the manner previously described. The rope was laid with Lang lay and a hemp-core, and is now in use for winding from a shaft 1,740 feet deep. The result of the test was on the whole unsatisfactory, and, although the margin between the working-load and the maximum stress was 42 tons, a much higher percentage of efficiency had been expected. The ratio of the holding-power of the capel to the breaking-load of the rope was 61·2 per cent. The writer intends to make further tests of ropes capeled in a manner somewhat similar to that described above, with various modifications and improvements which have suggested themselves to him; and he has every reason to think that a much improved capel will be the result, and that a much higher percentage will be attained.

Conclusion.—In conclusion, the writer would say that it is not within the bounds of human possibility to ensure absolute immunity from accident, but all means at one's disposal may be used to reduce the risk to a minimum. The best materials obtainable should be employed, and every care should be taken in the construction of the various appliances. All that then remains to be done is to exercise the utmost vigilance and care in the periodical examinations which are made, and at once to condemn and remove any part of the tackle which shows signs of defect or failure.

TABLE II.—TESTS OF A CAPEL AND OF A WINDING-ROPE, WITH A MAIN HEMP-CORE.

No. of test	(1)			(2)
Description of rope	Lang-lay wire-rope, after being in use, with a capel attached at one end.			Lang-lay wire-rope, cut from the same length of rope as that used in the first experiment.
Circumference of rope ... inches		5·35		5·40
Weight per fathom ... pounds		25·76		25·76
Strands:				
Number of strands		6		6
Number of wires		12 and 7		12 and 7
Diameter of wires ... inches		0·11		0·11
Total number of wires ...		114		114
	Elongation of the rope on a length of 25 inches.	Movement of the rope in the capel.	Closing of the shackle, EF.	Elongation of the rope on a length of 25 inches.
Stress: 1 ton .. ... inches	Zero.	Zero.	Zero.	Zero.
5 tons ... ,,	0·02	None.	None.	Zero.
10 ,, ... ,	0·08	None.	None.	0·05
15 ,, ... ,,	0·15	0·02	None.	...
20 ,, ... ,,	0·19	0·10	None.	0·12
30 ,, ... ,,	0·25	0·30	None.	0·20
40 ,, ... ,,	0·55	6·00	None.	0·25
50 ,, ... ,,	0·75	9·70	0·11	0·31
70 ,, ... ,,	...	...	...	0·43
90 ,, ... ,,	...	...	...	0·75
Maximum stress ... tons		57·40		93·72
Total elongation of rope inches		...		1·00

REMARKS.—(1) The rope rapidly pulled out of the socket with a load of 39·20 tons; the shackle, EF (Fig. 5, Plate XV.), began to close in with a load of 45 tons; and the pin, P, began to bend with a load of 50 tons. With a load of 57·40 tons, the rope broke inside the capel, at the place where the wires were bent over. There was no movement at AB or CD (Fig. 5, Plate XV.) during the test, but there was a permanent set of 0·20 inch on the shackle, EF, after the rope had been broken.

(2) One strand and some of the wires in one of the remaining strands broke together, clear of the fastenings.

Mr. R. HOLIDAY instanced a case that had come before his notice where, on examination of a rope, it was found that 50 feet of the core had disappeared. It was a balance-rope which had no great amount of weight on it, and absolutely no change was noticed on the outside of the rope.

Mr. BARRACLOUGH stated that the diameter of the drum, referred to in his paper, was 23 feet; that of the pulley on the stocks, 19 feet; and that of the pulley in the sump, about 6 feet.

Mr. I. Hodges said that he had found the same difficulties as Mr. Barraclough with wire-core winding-ropes. He had used them with the object of reducing the stretching with full loads, as compared with the empty cage; the difference was as much as 2 feet in a length of 1,200 feet and it was somewhat disconcerting to the winding engineman, particularly if his view of the cage was obstructed. The wire-core had the effect of keeping a more average length, but the reason for which he discarded the use of wire-cores was not because of any actual difficulty in the working, so much as in the making. A wire-core rope, 5½ inches in circumference, on being put to work, was found to be bulged so wide as to be unable to pass the groove of the winding-pulley. This bulging occurred at intervals, say, 150 to 300 feet apart. The manufacturer of the rope took it back and re-spun it; but, when it was returned the following week, it was just as bad. The manufacturer then spun it with a hemp core, and there was no further trouble. Previous winding-ropes, with wire-cores of the same quality of material and the same construction, had given no trouble, and they had certainly the advantage that the elongation of the rope due to heavy loads was nothing like so marked as with a hemp core. Of course, wire-core haulage-ropes were well-known; in fact, the bulk of the ropes that he used had wire-cores (so as to give less stretching on long lengths of haulage), and the fact that they retained their diameter on steep gradients was advantageous when using screw-clips.

THE MIDLAND COUNTIES INSTITUTION OF ENGINEERS AND THE MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD IN THE LECTURE HALL OF THE LITERARY AND PHILOSOPHICAL SOCIETY, SHEFFIELD, APRIL 10TH, 1906.

MR. W. G. PHILLIPS, IN THE CHAIR.

The SECRETARY announced the election of the following gentlemen to The Midland Counties Institution of Engineers:—

MEMBERS—

Mr. RENÉ FABRY, Civil Engineer, 24, Rue des Minimes, Brussels, Belgium.
Mr. LAURENCE HOLLAND, Mining Engineer, Hamstead Colliery, near Birmingham.
Mr. FITZ SEVERN, Director and General Manager, Claye's, Limited, Long Eaton, Derby.

ASSOCIATES—

Mr. HERBERT DANBY, Surveyor, Shirebrook Colliery, near Mansfield.
Mr. JOHN WESLEY HARVEY, Deputy Manager, Whaley Bridge, Stockport.

STUDENTS—

Mr. JOHN CHARLESWORTH CRAWSHAW, Mining Student, Dinnington Main Colliery, near Rotherham.
Mr. FRANK STEPHEN HANSON, Mining Student, Cloverlands, Kimberley, near Nottingham.
Mr. CLEMENT HEATHCOTE, Mining Student, Newstead Colliery, near Nottingham.

The following gentlemen were elected to the Midland Institute of Mining, Civil and Mechanical Engineers, having been previously nominated:—

MEMBERS—

Mr. JOHN BRASS, Colliery Manager, Houghton Main Colliery, near Barnsley.
Mr. JOSEPH ELSTOB, Colliery Manager, 31, Ferrybridge Road, Castleford.
Mr. HORACE JOHN JONES, Consulting Engineer, 72, Victoria Street, London, S.W.
Mr. HENRY PARKER LAWS, Engineer, Mountain View, Thornhill, Dewsbury.
Mr. WALTER MACHEN, Colliery Manager, Thorncliffe Collieries, near Sheffield.
Mr. HUGO PRESSER, Mining Engineer, Bettina Schacht, Dombrau, Silesia, Austria.
Mr. FRED ROBINSON, Under Manager, Wood Pit, New Mill, Huddersfield.
Mr. FRED SINGLETON, Colliery Surveyor and Manager's Assistant, Manvers Main Collieries, Wath-upon-Dearne, near Rotherham.
Mr. ERNEST WILLIAM TERRY, Civil Engineer, Priddock House, Lady Bower, Bamford, Derbyshire.
Mr. LAWFORD SIDNEY JOSEPH THOMSON, Surveyor and Manager's Assistant, Manvers Main Collieries, Wath-upon-Dearne, near Rotherham.

STUDENTS—

Mr. BASIL HENRY PICKERING, Mining Student, Lawn House, Doncaster.
Mr. EDGAR SCHOFIELD, Mining Apprentice, 20, Nowell View, Harehills Lane, Leeds.
Mr. GILBERT KIRK SMITH, Mining Student, Barnes Hall, Grenoside, Sheffield.

DISCUSSION OF MESSRS. G. BLAKE WALKER AND L. T. O'SHEA'S PAPER ON "THE UTILIZATION OF SURPLUS-GASES FROM BYE-PRODUCT COKE-OVENS."*

Dr. R. HERZFELD wrote that Mr. Blake Walker and Prof. O'Shea have shewn that an enormous amount of energy is stored in those gases which can be collected in coke-ovens, and what means have been developed by engineers to put this energy into mechanical effect. The question presenting itself for consideration in this connection is, how this mechanical effect may be applied to the best advantage, and there are two solutions which must be considered:—(1) Gas-engines can either be applied to the machinery direct within a reasonable radius; or (2) they can be used for the generation of electrical energy: the latter method having been found to be by far the most effective. Gas-engines, although developed to a very high standard, are not suited for very rough usage and should not be left to the unskilled hands of men employed at collieries and

* *Trans. Inst. M. E.*, 1905, vol. xxix., page 187; and vol. xxx., page 249.

iron-works. There are special and complicated details which demand particular treatment; their proper place, therefore, is in a suitable engine-house, away from dust and unforeseen occurrences associated with works; and the best use, to which they can be put, is in connection with electrical distribution. This also has the great advantage of allowing the individual units of gas-engines to run at their best efficiency, and to produce exactly the number of units which the time of day and the works may require. The electrical drive overcomes all the difficulties which would have to be met when applying gas-engines direct to the machinery in the way of variation of load, and particularly in connection with reversing and speed-control. Electricity affords very efficient means of balancing the variable loads of the driven machinery, achieving a very steady load on the generating station. These electrical balancing devices have been developed to so high a state of efficiency that, on a rolling-mill recently installed of 500 to 600 horsepower, the ammeter connected to the electrical motor did not vary more than 1 per cent., in spite of the great peaks with which the driving of this mill had to contend. Even those heavy jerks, which are encountered when accelerating reversing-mills or winding-engines, have been successfully overcome by electrical balancing devices, so that the load on the generating station comes out nearly constant, even with a reversing mill of 10,000 horsepower, reversing ten times a minute.

The generation of electricity by means of powerful gas-engines is not so easy a problem as is generally believed. It is necessary for the gearing of the gas-engine to be particularly sensitive in order to allow for the parallel running of alternators, which (for the sake of economical running) is required in large power-stations. A good deal can be done to further this purpose by heavy flywheel masses, and he (Dr. Herzfeld) would like to draw the attention of the members to a design for an alternator, which had lately been introduced and allowed of a heavy flywheel-effect, without the use of unduly large masses of metal and without complicated shafting. In this alternator, the inductor rotates outside the stator-windings, and gives a heavy flywheel-effect in a very effective manner. Two of these alternators, one of 1,200 horsepower and one of 900 horsepower, will shortly be running at the Bargoed colliery of the Powell

Duffryn Steam Coal Company, Limited, and at the Brymbo steel and iron-works. In his (Dr. Herzfeld's) opinion the advantages to be derived from the use of coke-oven gas will be materially increased by the adoption of electrical drives throughout collieries and adjacent works; and it is hardly possible to turn coke-oven gas to profitable account by any other means. Electrical drives have proved themselves to be eminently satisfactory for every kind of mining or iron-work operation, and the conversion of huge reversing rolling-mills from steam to electricity, which has been adopted in order to increase the output of mills by way of quicker acceleration and retardation, represents the latest and most improved example of the application of electricity. It would appear that the facilities for the employment of electrical energy on a large scale, afforded by the use of waste-gases, should be regarded as their chief merit.

Mr. W. Price Abell read the following paper on "The Reavell Air-compressor at Work":—

THE REAVELL AIR-COMPRESSOR AT WORK.

By W. PRICE ABELL.

Following the author's previous paper dealing with the details and types of the high-speed air-compressor developed by Mr. W. Reavell for colliery and mining work, it will be interesting now to consider briefly a few of the advantages which attend the working of some of these machines.

Coal-cutting Machines.—Last year, over 6,744,000 tons of coal were cut by machinery; and, in doing this, 485 machines were driven by compressed air and 270 by electricity. It has become almost an axiom that many of the thinner seams must, in future, be undercut by mechanical means, if they are to be worked economically; but, unfortunately, the data available by the author to place before the members are not complete. He has been surprized at the demand made by all makers of coal-cutting machines for a supply of air at a pressure of 50 to 60 pounds per square inch; and it was only after going very carefully into the working details, and taking indicator-diagrams, that he arrived at the fact that this high pressure was necessary or, in other words, that the large cylinders on the coal-cutters were necessary, owing to the loss of efficiency in the pipe-lines, as dealt with in his aforementioned paper.

The following typical case illustrates, perhaps, the average working, from which it will be seen that, although the bank-pressure was 60 pounds per square inch, a pressure of only 20 pounds was usually available and necessary for working the coal-cutter. This fully bears out the recognized practice that for 100 horsepower at the air-compressor at bank not more than 20 horsepower is delivered at the coal-face. The piston-speed was 450 feet per minute. The crank made 300 revolutions, and the cutting-wheel 14 revolutions per minute. The average air-pressures per square inch were as follow: On piston, 15 pounds;

on stop-valve, 30 pounds; below stop-valve, 20 pounds; at bank, 60 pounds. The cutting-wheel was 5½ feet in diameter, and a length of 1,500 feet was cut in 16 hours.

In another case, the piston-speed was 360 feet per minute, and the air-pressure on the piston was 18 pounds per square inch. The crank-shaft made 240 revolutions per minute, and the cutting-wheel, 5½ feet in diameter, made 11½ to 14 revolutions per minute.

In another case, a Diamond coal-cutter, having two cylinders, 9½ inches in diameter and of 8 inches stroke, was undercutting to a depth of 4½ feet in a very stiff fire-clay, at the rate of 36 feet per hour. A pressure-gauge, screwed on to the machine-side of the stop-cock, and therefore approximately in a position to show the pressure of the air supplied to the coal-cutter, showed an air-pressure of 11 pounds per square inch; and under these conditions the crank-shaft made 250 revolutions per minute.

It is an obvious conclusion that the enormous loss, entailed by the conveyance of air from an air-compressor at bank to coal-cutters in the mine, could be avoided by "in-bye" compression: the air would then be delivered from the air-compressor to the coal-cutting machine through a short length of pipe, with consequent low friction and leakage-losses, giving a combined efficiency of 64 per cent., as detailed in the author's previous paper.

Heading Machines.—A rotary type Stanley header driven by air supplied from an air-compressor at bank practically suffers the high losses shown in the preceding paragraph. This machine working in a seam 21 feet thick, in the Nuneaton district, in actual practice works with an air-pressure of 20 pounds per square inch, while the pipes-lines are supplied from the pit-head compressor-system with air at a pressure of 60 pounds per square inch. The pressure-gauge, screwed right on the inlet-pipe to the heading-machine at the face, shewed that the actual air-pressure in the cylinder of the heading machine never exceeded 25 pounds per square inch when the machine was running; and it fluctuated from 18 to 20 pounds. This showed that a very large frictional loss was taking place in the "in-bye" pipes between the bank-compressor and the Stanley header. Of course, the writer is aware of the arguments fre-

quently raised, that this is not really a loss: one argument being based on the ground that, although the air is falling in pressure it is correspondingly increasing in volume. This is true, so far as it goes, but one must not overlook the fact that if all that is required is to deliver air at a lower pressure to modern heading and coal-cutting machines; then, if the air can be compressed to only the pressure required (this work being readily done close to the face by an electrically-driven air-compressor), it is obvious that a very much smaller power would be required to compress the air to this lower pressure than is actually used at bank to compress the air to a higher pressure, and afterwards have it wire-drawn and reduced in pressure.

Electrically-driven Air-compressors.—At the same colliery, in the Nuneaton district, in another part of the mine, an electrically-driven Reavell air-compressor is supplying air at a pressure of 29 pounds per square inch to a Stanley header similar to that from which the aforementioned data were supplied. This compressor was fixed within a few feet of the point where the header started. It was driven by continuous current at 500 volts, and arranged to cut out automatically whenever the air-pressure exceeded 29 pounds per square inch. The header worked easily when supplied with air at an average pressure of 20 pounds per square inch; but this was exceeded when the machine was choked or passed into harder material. Rapid work was effected with a maximum occasional pressure of 29 pounds per square inch.

The author saw this Stanley header working, a few weeks ago, about 900 feet distant from the Reavell compressor. The air was carried to it through a pipe, 4 inches in diameter. It was then working at an average air-pressure varying from 20 to 24 pounds per square inch, as the machine seldom required more. The automatic cut-off worked regularly and quite automatically without trouble, at an air-pressure of 29 pounds per square inch.

The author discussed the work with Mr. J. H. W. Laverick, who expressed the opinion that it would be an advantage to have a maximum cut-out, working at a pressure of 40 pounds per square inch, available in cases of emergency: not that it was necessary regularly, but for use in hard places, when the

machine could work at a slower speed. The motor would be sufficiently powerful to supply a less quantity of air, in cases of emergency, at a pressure of 40 pounds per square inch. Of course, where the coal is soft, the average pressure of 20 pounds is more than ample. It would only be in cases of emergency, such as a block, that the higher pressure of 40 pounds and the less quantity would be of advantage.

The air-filter on the side of this compressor practically prevents any trouble that might arise through dust getting into the machine, and admirably serves the purpose for which it was designed.

Another important point, in connection with the working of this compressor and the Stanley header, was observed: namely, that the heading machine only runs 2 to 2½ minutes at a time, and that for 90 per cent. of its time it is standing, while the men are clearing away the spoil, shifting machinery, etc. This, of course, gives rise to very marked economy, the automatic cut-off bringing the air-compressor to a stand, while for 90 per cent. of the time the bank air-compressor, under similar conditions, would be obliged to run.

As a matter of fact, in this particular instance, the average input into the motor was between 35 and 40 kilowatts; and, taking the cost of current at 1d. per kilowatt-hour, the cost per hour for cutting 1 foot of heading would be (35 kilowatts $\times$ 9 minutes $\div$ 60 minutes $=$) 5d.

Percussive Machines.—In the case of percussive machines, such as the Little Hardy, the Champion, etc., the same conditions apply, except that when a pressure of 60 pounds per square inch is required, for holing in soft material, a Reavell single stage air-compressor may be employed; and, when a pressure of 90 pounds per square inch is required, for holing in hard material, an economy will accrue from the use of a Reavell two-stage air-compressor.

Percussive Drills.—Closely allied to heading with percussive drills comes quarry work, also requiring the use of percussive drills. In this case, in the past, it has been the practice to use steam-drills, with heavy condensation pipe-losses, especially in cold weather, accompanied by great waste of steam, preventing

the drills from getting the high initial pressure necessary for economical work, whilst the drill is not so handy as when fed with compressed air.

The differences in this respect alone will more than pay for the unavoidable losses due to the double conversion of energy involved by using electricity; and the saving in labour by having the enginehouse-men looking after the generators would be a clear gain. Further, the electric generator would use much less steam per horsepower than would be required for feeding the drills directly with steam, and consequently there would also be a saving in fuel.

Another very important advantage possessed by the Reavell air-compressor is its portability. Consequently, it can be placed near to the drills in the quarry; and the efficiency, by the avoidance of consequent leaks and friction, may be raised from 20 to 70 per cent. For this class of work, it is advisable to use a Reavell two-stage air-compressor.

The author has to thank members, who have so kindly given assistance and data, which make this subject particularly attractive to those who attach importance to economy, not only of coal but also of the steam-producing plant. The capital outlay saved in boilers alone for an economical air-compressing plant, shows up and opens out a field for enormous saving.

Mr. W. Reavell said he wished to refer specially to that part of Mr. Abell's paper in which he mentioned the losses inseparable from pit-head compression at a pressure of 60 pounds per square inch, when the air was to be used in coal-cutters. He thought that a false analogy was too often drawn between the use of steam and air under pressure and the effect of latent heat was overlooked. The fact, of course, was that when latent heat was overcome and steam was once generated in a boiler, very little additional heat-energy was required to raise the pressure considerably and to increase its capacity for work in the same proportion. With compressed air, on the other hand, whatever pressure was used beyond that absolutely required, meant an additional and correspondingly equal amount of wasted energy expended in the air-compressor.

He (Mr. Reavell) thought that it should be taken as an

axiom that, other things being equal and within common-sense limits, the lower the pressure the better the efficiency. Applying this to the question of coal-cutting machines, he had prepared Figs. 1 and 2 to illustrate the difference between pit-head and in-bye compression, and also to indicate another source of considerable saving. The full black lines (Fig. 1) represented a theoretical diagram taken from a coal-cutter cylinder, with an initial pressure of 20 pounds per square inch and cutting off at 90 per cent. of the stroke. He had collected information as

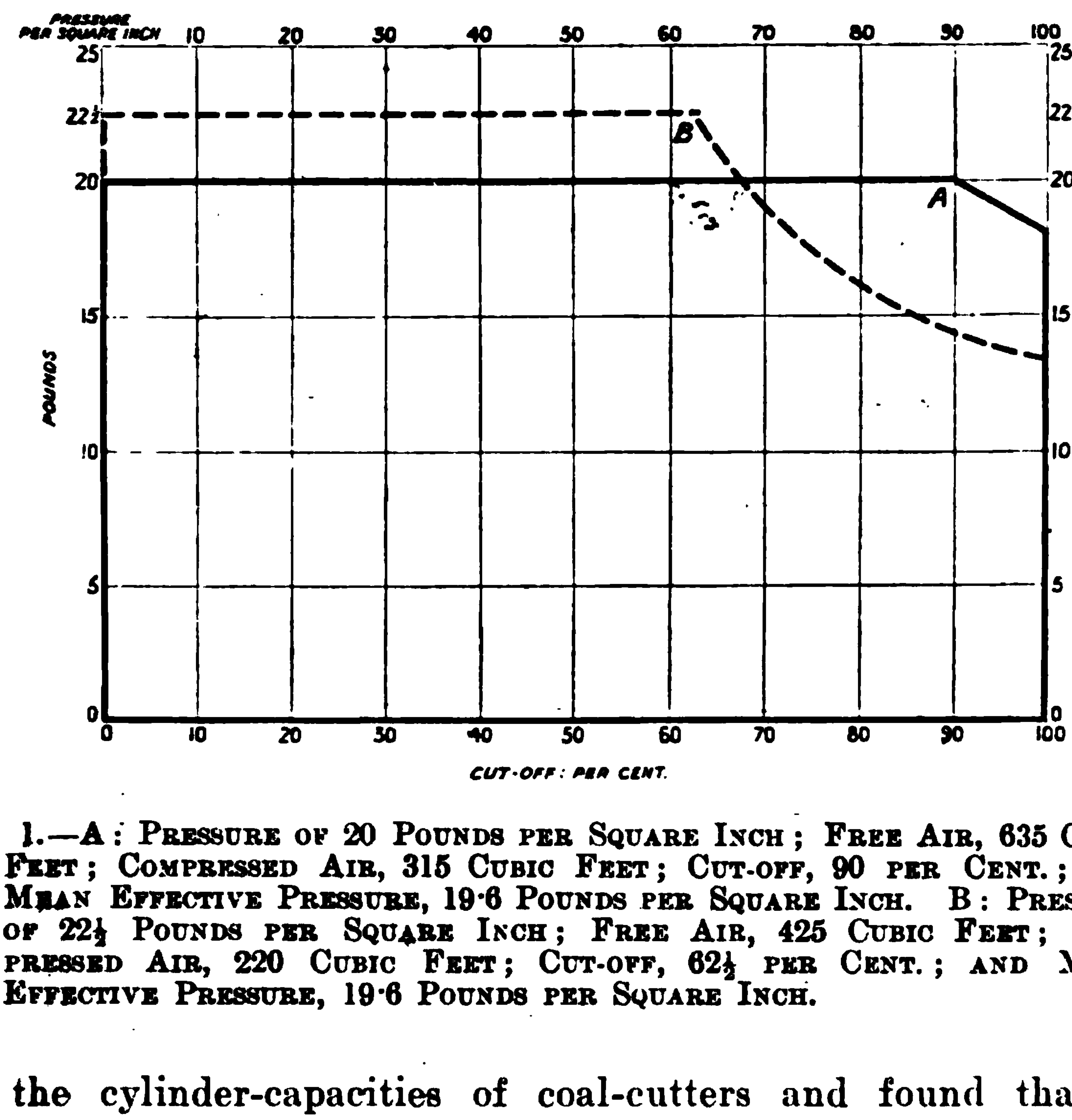

FIG. 1.—A: PRESSURE OF 20 POUNDS PER SQUARE INCH; FREE AIR, 635 CUBIC FEET; COMPRESSED AIR, 315 CUBIC FEET; CUT-OFF, 90 PER CENT.; AND MEAN EFFECTIVE PRESSURE, 19·6 POUNDS PER SQUARE INCH. B: PRESSURE OF 22½ POUNDS PER SQUARE INCH; FREE AIR, 425 CUBIC FEET; COMPRESSED AIR, 220 CUBIC FEET; CUT-OFF, 62½ PER CENT.; AND MEAN EFFECTIVE PRESSURE, 19·6 POUNDS PER SQUARE INCH.

to the cylinder-capacities of coal-cutters and found that a machine with two cylinders, 9½ inches in diameter and 9 inches stroke, might be taken as an average. At a speed of 230 to 250 revolutions per minute, the cylinder-volume would be, say, 350 cubic feet; and, allowing for cutting-off at 90 per cent. of the stroke, the quantity of air required at a pressure of 20 pounds per square inch would be 315 cubic feet per minute. The members would probably agree that indicator-diagrams taken from coal-cutters showed actually a lower pressure than

20 pounds per square inch, and that this figure was ample. An indicator-diagram taken under these conditions would show 30 horsepower, which would be ample; and, as further corroboration, it might be mentioned that electrically-driven compressors of this type were only fitted with one motor of 20 horsepower, or two motors of 10 horsepower each. Seeing, therefore, that a pressure of 20 pounds per square inch was ample for working a coal-cutter and that a pressure of 60 pounds per square inch, and, in more recent times, 70 and 80 pounds per square inch, was common at bank, he would leave the members to decide how the loss came about, and would merely point out that serious waste was taking place.

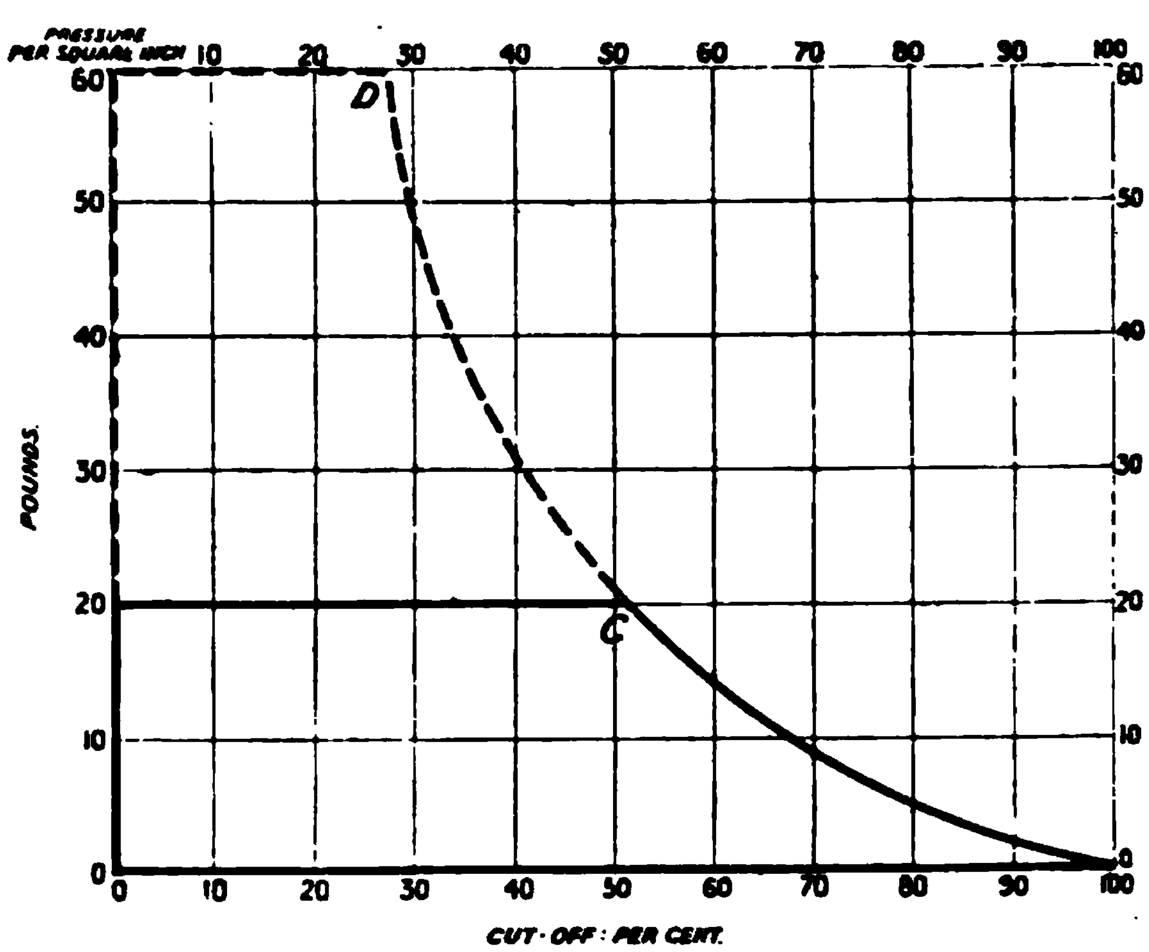

FIG. 2.—C: PRESSURE OF 20 POUNDS PER SQUARE INCH; FREE AIR, 635 CUBIC FEET; COMPRESSED AIR, 315 CUBIC FEET; AND MEAN EFFECTIVE PRESSURE, 14·47 POUNDS PER SQUARE INCH. D: PRESSURE OF 60 POUNDS PER SQUARE INCH; FREE AIR, 735 CUBIC FEET; AND MEAN EFFECTIVE PRESSURE, 31·17 POUNDS PER SQUARE INCH.

With pit-head compression of 60 pounds and in-bye compression of 20 pounds per square inch, he would, now, show what this loss amounted to. Assuming that an in-bye electrically-driven air-compressor was used, and that it could be placed relatively close to the coal-cutter, and connected thereto by a pipe, 4 inches in diameter, the drop in pressure would be negligible; and the full lines (Fig. 2) shew the indicator-diagram that would be obtained from the air-compressor. With ordinary

water-jacketing and, say, 40 per cent. absorption of the heat of compression, the mean effective pressure would be 14·47 pounds per square inch, the equivalent free air would be 635 cubic feet, and 40 horsepower would be required for compression. The dotted lines (Fig. 2) shew the energy required to compress up to a pressure of 60 pounds per square inch and the mean effective pressure under the same conditions would be 31·17 pounds per square inch. A larger equivalent quantity of free air would be required, because the air compressed at bank and delivered at a fairly high temperature from the compressor would be rapidly cooled down to the temperature of the mine before it had travelled far along the air-mains; consequently, the air-compressor capacity at bank, to supply 315 cubic feet to the coal-cutter cylinders at a pressure of 20 pounds per square inch, would be 735 cubic feet; and the horsepower indicated in the air-compressor cylinder at bank would be 100, as compared with 40 in the in-bye compressor.

It was common knowledge that no attempt was made to use the air expansively in coal-cutter cylinders, for the equally well-known reason that the result was the production of fog and even of ice in the exhaust parts. The dotted lines (Fig. 1) shewed an indicator-card equal in area and power to the full-line card. It was obtained by raising the air-pressure to 22½ pounds (an increase of 2½ pounds) per square inch and cutting off at 62½ per cent. of the stroke. When using air expansively under these conditions, the resultant temperature of the exhaust-air would be considerably below freezing point: the actual figure being 0° Fahr., if the air reached the coal-cutter cylinders at, say, the mine-temperature of 70° Fahr. If, however, the air reached the coal-cutter at a temperature of, say, 150° Fahr., it would then be possible to cut off at 62½ per cent. of the stroke, to save one-third of the air, and to exhaust the air at about the temperature of the mine. He (Mr. Reavell) proposed to do this by still further simplifying and cheapening the in-bye compressor, removing the water-jacket, and thus avoiding the necessity of providing a supply of jacket-water. Instead, he would lag the cylinders of the compressor with non-conducting composition and cover the pipes from the air-compressor to the coal-cutter with asbestos rope. Under these conditions, if the air was compressed to 22½ pounds instead of 20 pounds per square

inch, the temperature would be about 200° Fahr., and the air would reach the coal-cutter hot enough for the expansion referred to. The volume of air required (Fig. 1) by the coal-cutter would now be 220 cubic feet instead of 315 cubic feet, and the free-air capacity of the compressor would now be 425 cubic feet instead of 635 cubic feet. Owing to the air being compressed adiabatically, the mean effective pressure would naturally rise, the value becoming 17·2 pounds per square inch; but, owing to the great saving in the size of the compressor, the horsepower required would only be 32 instead of 40.

The results may be epitomized as follows:—(1) Pit-head compression of air to a pressure of 60 pounds per square inch requires a compressor-capacity of 735 cubic feet and 100 horsepower. (2) In-bye compression of air to a pressure of 20 pounds per square inch, with a jacketed compressor, requires a compressor-capacity of 635 cubic feet and 40 horsepower; while, for the new method proposed, a compressor with a capacity of 425 cubic feet, at a pressure of 22½ pounds per square inch, will suffice and 32 horsepower will be required. He would not advance these figures as being correct for all conditions, but they were certainly proportionally correct and he considered, where pneumatic coal-cutters were used, that the plan suggested merited the serious consideration of mining engineers.

Mr. M. DEACON said that he had used the Reavell air-compressor in more than one pit and for more than one purpose, and he was bound to say that he had formed a favourable impression of it; but, although there was little doubt as to the advantage of having the air-compressor near to the face if it were necessary to use compressed air, he was satisfied that most work could be done more economically by electricity. With regard to Mr. Reavell's proposal to use the air in the cylinders expansively, to be effective, this would necessitate a moderately high pressure of air, say, 60 to 80 pounds per square inch at the air-compressor. He (Mr. Deacon) thought that, in single compression, there would be a greater loss of power by radiation of heat due to this somewhat high pressure than the economy gained in expansion. He would like to know whether Mr. Reavell had made any experiments in this direction, confirming the advantage that he claimed.

The CHAIRMAN (Mr. W. G. Phillips) proposed a vote of thanks to Mr. W. Price Abell for his paper.

Mr. ISAAC HODGES seconded the resolution, which was cordially approved.

The discussion was adjourned.

Mr. T. BEACH's paper on "'Black Ends:' Their Cause, Cost and Cure" was read as follows:—

"BLACK ENDS:" THEIR CAUSE, COST AND CURE.

By T. BEACH.

"*Black Ends.*"—Rather more than a year ago, Mr. George B. Walker, in the course of a lecture given at Chesterfield, made use of the following words:—"The coal at the end of the oven resting against the door is only slightly carbonized."* This led the writer, who had been previously much annoyed at the evident waste taking place at the ovens under his charge, to enquire more minutely into the cause, to ascertain from experiment the actual cost, and if possible to find a cure, for such waste.

Cause.—The cause of the so-called "black ends" is obvious, and may be summed up in two words, namely, "insufficient heat," which may arise from a variety of conditions, such as:—(1) A cold wind blowing on to the oven-ends. (2) The first flues in the side-walls (where vertical flues are in use) not attaining the temperature of the second and subsequent flues, owing to the cooling action of the atmosphere. (3) The doors not being sufficiently recessed, between the side-walls of the oven. And (4) the chilling action produced by the solid door, which is in contact with the only part of the charge of coal that is not resting against incandescent walls.

Cost.—The cost of the "black ends" is a somewhat difficult matter to ascertain. Under different circumstances, it will undoubtedly vary very considerably; and the writer would wish it to be borne in mind that the figures which are hereafter given must only be taken as applying to those particular ovens upon which the experiments have been made.

These were carried out last autumn, and in February of this year, by having the unburnt slack and seconds coke carefully weighed from three successive drawings of each individual oven,

* *Minutes of Proceedings of the National Association of Colliery Managers*, 1905, vol. ii., page 299.

and the latter again taken over a week's work of the whole battery. The figures referring to February, 1906, are about 10 per cent. less than those taken last autumn, and the writer, wishing to avoid any exaggeration, has adopted the lower ones. It will be noticed that the effect of cold winds is shewn by the results, as in every case the quantity of waste slack is greater at the bench-end, which is exposed to the north and east, than at the ram-end, which is sheltered by the recovery-plant buildings and a high dirt-stack.

As regards seconds coke, it may be argued that, at many (and possibly the majority of) coking plants, no coke whatever is sold as seconds; but it is submitted with a considerable amount of confidence that wherever a "black end" exists, a piece of coke of an inferior quality is produced, and although a small percentage of this may be of no very great moment when used for blast-furnace purposes, in the case of malting coke it is imperative that it should be most carefully excluded, as the presence of even a very small quantity of imperfectly burnt smudge will inevitably result in smoked barley, complaints, and, if repeated, loss of trade.

Collins Coke-ovens.—The Snydale battery consists of 45 Collins ovens, with vertical flues. These are all connected and worked as one installation, although the last 15 ovens were built at a later date, and are in reality an extension of the original 30 ovens. Each oven is 33½ feet long, 6½ feet high to the spring of the arch, and 18½ and 16½ inches wide at the bench-end and ram-end respectively. The first 30 ovens were built with neither of the doors recessed (Fig. 1, Plate XVI.); and last summer, when a number of these were being repaired, it was decided to recess the doors to the extent of 5 inches, so as to bring the charge of coal into line with the first flues in the side-walls (Fig. 2, Plate XVI.); but time and circumstances only allowed of this being done at the ram-end, and so there are now a certain number of ovens with one door recessed. The last 15 ovens have both doors recessed (Fig. 2, Plate XVI.).

The actual amount of seconds coke produced from the ovens referred to in Tables I., II. and III., amounted to 3,124 pounds, or an average of 173 pounds per oven. The accuracy of this result is corroborated by the weekly return of seconds coke,

namely, two wagons of about 8 tons each from 210 ovens drawn, or an average of 170 pounds per oven, and, with 36 hours charges, this equals 18·4 tons per oven per annum.

TABLE I.—WASTE SLACK PRODUCED FROM COKE-OVENS WITH NEITHER OF THE DOORS RECESSED.

No. of Oven.	Dates when Drawn.	Waste Slack. Ram-end. Pounds.	Waste Slack. Bench-end. Pounds.	Total. Pounds.	Total Waste per Annum, with 36 Hours Charges. Tons.
23	1906, Feb. 15	38	64	102	
,,	,, 21	28	78	106	
,,	,, 27	27	50	77	
25	,, 20	29	62	91	
,,	,, 23	29	42	71	
,,	,, 26	40	53	93	
	Totals	191	349	540	
	Averages ...	32	58	90	9·77

TABLE II.—WASTE SLACK PRODUCED FROM COKE-OVENS WITH ONE DOOR RECESSED.

No. of Oven.	Dates when Drawn.	Waste Slack. Ram-end. Pounds.	Waste Slack. Bench-end Pounds.	Total. Pounds.	Total Waste per Annum, with 36 Hours Charges. Tons.
5	1906, Feb. 17	24	51	75	
,,	,, 20	18	50	68	
,,	,, 23	19	54	73	
10	,, 20	16	44	60	
,,	,, 23	12	44	56	
,,	,, 26	14	59	73	
	Totals	103	302	405	
	Averages ...	17	50	67	7·27

TABLE III.—WASTE SLACK PRODUCED FROM COKE-OVENS WITH BOTH DOORS RECESSED.

No. of Oven.	Dates when Drawn.	Waste Slack. Ram-end. Pounds.	Waste Slack. Bench-end. Pounds.	Total. Pounds.	Total Waste per Annum, with 36 Hours Charges. Tons.
35	1906, Feb. 16	12	31	43	
,,	,, 19	14	19	33	
,,	,, 22	17	26	43	
40	,, 15	17	57	74	
,,	,, 21	19	33	52	
,,	,, 27	nil	19	19	
	Totals	79	185	264	
	Averages ...	13	31	44	4·78

Putting the above results into money, and taking the value of coke at an average price of 12s. per ton, the difference in

value between seconds and best coke at 5s. per ton, and the value of the bye-products at 3s. 3d. per ton of coal, the wastage is recorded in Tables IV., V. and VI.

TABLE IV.—VALUE OF THE WASTAGE AT COKE-OVENS WITH NEITHER OF THE DOORS RECESSED.

	£	s.	d.
9·77 tons of slack, yielding 70 per cent. of coke, 6·83 tons at 12s.	4	2	0
18·4 tons of seconds coke converted into best coke, at 5s. ...	4	12	0
Bye-products on 9·77 tons, at 3s. 3d.	1	11	9
Total wastage per oven per annum ...	£10	5	9

TABLE V.—VALUE OF THE WASTAGE AT COKE-OVENS WITH ONE DOOR RECESSED.

	£	s.	d.
7·27 tons of slack, yielding 70 per cent. of coke, 5·09 tons at 12s.	3	1	0
18·4 tons of seconds coke converted into best coke at 5s. ...	4	12	0
Bye-products on 7·27 tons, at 3s. 3d.	1	3	7
Total wastage per oven per annum ...	£8	16	7

TABLE VI.—VALUE OF THE WASTAGE AT COKE-OVENS WITH BOTH DOORS RECESSED.

	£	s.	d.
4·78 tons of slack, yielding 70 per cent. of coke, 3·34 tons at 12s.	2	0	1
18·4 tons of seconds coke converted into best coke at 5s. ...	4	12	0
Bye-products on 4·78 tons, at 3s. 3d.	0	15	6
Total wastage per oven per annum ...	£7	7	7

The recessing of the doors, however satisfactory it may be as regards the minimizing of the "black ends," has the great disadvantage of materially reducing the oven-capacity; and, if done to the extent of only 5 inches at each end, means, in an oven 18 inches wide and 5 feet high, a loss of 6·25 cubic feet. On charges burning for 36 hours, taking the weight of a cubic foot of coke at 39 pounds, the loss is nearly 26½ tons of coke per oven per annum: a loss of output surely worthy of consideration.

Flued Doors.—With a view to overcoming the beforementioned disadvantages and losses, and at the same time avoiding the reduction of oven-capacity and consequent loss of output, a flued door (Figs. 3 to 8, Plate XVI.) has been designed. It may briefly be described as a door having an internal vertical

flue of sinuous or zig-zag formation, with an external gas-admission aperture at the base and an external escape-port at the upper extremity, for the purpose of burning purified or other gas in the said flue, so as to heat that portion of the door in contact with the charge of coal within the oven to a state of incandescence, thus driving off all gases contained in the said charge of coal, which may not come under the influence of the heated flues in the side-walls of the oven, and thereby ensuring the complete and perfect carbonization of the entire

FIG. 9.—FLUED DOORS AND PIPE-CONNECTIONS FOR SUPPLYING GAS.

charge of coal within the oven. The external admission and escape-ports are provided with sliding shutters, which should be closed whenever the gas is not burning in the flue in order to exclude cold air, thus retaining, as far as possible, the heat of the door and preventing extreme changes of temperature.

The flue is formed by specially-designed fire-clay blocks which fit the door, and which can be built in by any ordinary bricklayer in less time than it takes to line the door in the usual way. The

blocks cost from 2s. 6d. to 3s. per door more than the bricks that they replace, but an advantage is gained in the shorter time occupied in setting them in the door frame.

It will be seen that there is no internal communication with the oven, so that an increase in the bye-products, in proportion to the extra amount of slack carbonized (which was previously wasted), is ensured.

The general arrangements of the doors and the pipe-connections for supplying gas are shewn in Fig. 9.

In designing and laying out gas-plant to be used in connection with retort coke-ovens, it should be remembered that the quantity of surplus gas over and above that required for heating the ovens, and available for power-generation, will necessarily be a very variable quantity owing to:—(1) Different qualities of coal being used, yielding different amounts of gas; (2) the condition of the side-walls as regards leakage; (3) the number of ovens at work; etc. It will, therefore, always be necessary to allow an ample margin, or, in other words, it would be highly imprudent to equip the works with costly gas-engines relying upon the maximum quantity of gas to be always available. In the chain, the strength is only that of its weakest link, and in a like manner the minimum surplus supply can only safely be reckoned upon as available for power-generation. Again, assuming the maximum quantity to be available, there are many times, such as nights, holidays and week-ends, when the total engine-power will not be required; and, the storage of gas except in very considerable units being prohibited by capital expenditure, it is the surplus over and above the engine-power requirements, that is, the difference between the minimum and maximum surplus supplies, that can beneficially be used for burning off the "black ends," and so increasing, possibly by only a small extent, the gas-supply.

Messrs. G. B. Walker and L. T. O'Shea state that "the primary use of the gas is to heat the ovens, and only the surplus is available for power-generation "* and the writer contends that the gas burnt in the door is equally well used, and used for exactly the same purpose as that burnt in the flue-walls, namely, for the heating of the oven and the carbonizing of the coal contained therein.

* *Trans. Inst. M. E.*, 1905, vol. xxix., page 192.

As regards the quantity of gas consumed, it is surprizing how little is necessary, and it is only requisite that a tongue of flame be occasionally seen at the upper or escape-aperture, for sufficient heat to be generated to cause the inside lining adjoining the coal to glow. A tap, $\frac{1}{4}$ inch in diameter, would give an ample supply, but the writer has adopted a tap, $\frac{1}{2}$ inch in diameter, as easier to keep clean; this has to be kept turned half or three-quarters off to regulate the supply.

FIG. 10.—"BLACK ENDS" BURNT OFF AND CONVERTED INTO BEST COKE BY MEANS OF THE FLUED DOOR.

Another advantage derived from the use of the above-described door is that a hard clean face of coke (Fig. 10) is formed for the ram to push against; and it must be admitted that this is preferable to several inches of soft spongy material (Fig. 11) which is liable to squeeze out sideways, and may easily cause the coke to stick, particularly if the sides of the oven are rough and irregular from long and continual use.

In conclusion, it may be said that several of these doors have

been used experimentally at Snydale colliery since August, 1905, and have proved their efficiency (and are little, if any, the worse after 8 months' wear) by producing coke at the extreme ends of the oven, equal in quality to that which is to be found in any other portion of the oven, thus entirely eliminating all loss from unburnt slack and seconds coke from those ovens to which they have been fitted.

FIG. 11.—"BLACK ENDS" RESULTING FROM THE USE OF THE SOLID DOOR.

Mr. J. McCutcheon exhibited and described his apparatus for the detection of minute quantities of fire-damp.*

Mr. ARTHUR HALL's paper on "The Stanley Double-heading Machine" was read as follows:—

* "The McCutcheon Gas-detector," by Mr. R. McLaren, *Trans. Inst. M. E.*, 1906, vol. xxxi., page 237.

THE STANLEY DOUBLE-HEADING MACHINE.

By ARTHUR HALL.

Some time ago, Mr. Reginald Stanley read a paper on his heading machine at a meeting of the members of this Institute held in this city (Sheffield). That paper gave the history, and also a plenary description, of the machines (which were all of the single type) as worked up to that time, together with the various methods adopted for the driving of the same, namely, by hand-power, by water-power, and by means of compressed air. A full account of the results obtained was also given.*

Since then, however, although the fundamental principle remains the same, the machines have undergone considerable alterations and additions, and greatly increased efficiency as well as other advantages have resulted. Rope-driven and electrically-driven machines have also since been designed. The latter is a single, 5 feet in diameter, annular groove machine, to which, some 14 years ago, a continuous-current electric motor was fitted. This machine was put to work by Mr. King Harrison, of Stourbridge, and did some good cutting, but sometimes, when the coal fell in such a way as to cause an obstruction to the cutting arms, the fuses would blow. This was not, however, so great a disadvantage to the progress made with the heading as the size of the motor, which proved to be too unwieldy, taking up too much room; but motors to give the same power are, nowadays, made much smaller and more compact, and this difficulty would therefore not occur.

At first, single machines only were used, that is, machines cutting a circular head in diameters varying from 4 feet to 7½ feet. Some of these were designed to cut an annular groove, leaving a core of coal. Other machines were constructed to take out the full cut of the particular diameter of the machine. A machine of this description was fitted with a worm-conveyor

* "Stanley Coal-heading Machine," by Mr. R. Stanley, *Transactions of the Midland Counties Institution of Engineers*, 1888, vol. xvi., page 192.

to facilitate the removal of the coal in heading, which in this case is mostly slack. These machines will cut an average distance of 15 feet in a shift of 8 hours.

As the majority of the members of this Institute are no doubt familiar with these single heading machines, the writer does not deem it necessary to give any further detailed description here. It may, however, be stated that no less than 123 single machines, to cut up to 7 feet in diameter, have been made up to the present time, and have proved highly successful in every case where they have been worked under the suitable and normal conditions for which they were intended.

Subsequently, Mr. Stanley brought out the double- or duplex-heading machine. This was designed to cut a wider or double road, so as to admit of two lines of rails being laid, for endless haulage, etc.: the largest size yet constructed will cut a road, 12 feet wide and 6 feet high. This machine practically consists of two single machines joined and working together, with the cutting arms placed at right angles to each other, and overlapping in the cut; but, in this case, the cylinders, instead of being vertical as in the single machine, are placed horizontally, leaving a space in the central upper portion, which is fitted with a smooth plate, over which the coal and slack made in the heading can be thrown back. The coal and slack can also be thrown past each side of the machine, if found desirable, and smooth hinged plates can also be attached for this purpose as in the single heading machine. The three spaces, therefore, greatly facilitate the removal of the coal and slack, an operation which has in the past been found to take up far more time than the actual cutting. The different parts of the machine (Figs. 1 and 2, Plate XVII.) are as follows: A, framework of machine, made of steel angle-irons, 6 inches by 4 inches; B, cylinders; C, connecting-rod; D, compressed-air feed; E, first-motion shaft from engine; F, double carriage to carry front end of first-motion shaft; G, bevel-wheels on crank-shaft and shaft, E; H and H_1, first and second gear-wheels for driving, J and J_1, third and fourth gear-wheels driving on the centre shaft, K; L, L_1, L_2 and L_3, back and forward propelling gear; V, cutter-arm; W and W_1, cutting wings and cutting knives; X, side stays for spragging the machine; and Y, wheels carrying the machine.

The cutting arms of the double machine work in opposite directions, that is, one clockwise, and the other counter-clockwise; and they can be arranged, either to tend to bring the coal and slack towards the sides of the head (Fig. 3, Plate XVII.), or towards the centre of the head (Fig. 4). The small triangular-shaped pieces left on at the points A (Figs. 3 and 4), are readily trimmed off by hand, either at the front or at the back of the machine, after cutting, thus making an even roof and floor, and the side corners at the points A_1 (Figs. 3 and 4) can be made square, in like manner, if desired or should circumstances require it.

Five double machines, cutting a heading, 8 feet 6 inches wide and 5 feet 4 inches high, were put to work at the Rylands Main colliery, Barnsley, in 1891. They worked very successfully until the closing of the colliery, the rate of cutting being 7 lineal feet per shift of 8 hours. The writer regrets that no figures are now available showing the costs, as compared with hand-heading. Fig. 5 (Plate XVII.), is a section of the cutting. The fire-clay, 1 foot 8 inches thick, was very tough, having to be picked off in small pieces, and, even blasting had to be resorted to, when possible. The machines worked on the level, and both uphill and downhill, at a gradient of 1 in 12.

In the summer of 1905, Mr. Stanley designed a much improved form of the double machine (Figs. 6 and 7, Plate XVII.). It may be noticed that in general principle it is practically the same as the double machine, previously described, except that, in this case, the cylinders and driving gears are placed at the top instead of at the bottom of the machine, thus leaving a good clear space at the floor-level, between the feeding screws for the coal to be passed through, an operation which is performed much more quickly and easily than in the other machine, where the cylinders are placed at the base, and the coal has to be lifted up to, and passed over, the centre plate, or past the sides, as previously mentioned. The lettering and description of the double machine (Figs. 1 and 2) apply also to this machine (Figs. 6 and 7, Plate XVII.) so far as they go.

In the autumn of 1905, two double machines were put to work at the Charity colliery, Bedworth, to drive main hills

in the Ryder coal-seam: the headings dipping at the rate of 1 in 6. One of these machines had its cylinders and gear placed at the base, as previously described; and in the other they were placed uppermost, as last described. Each machine made a cut 9 feet wide and 5 feet 4 inches high (Fig. 8, Plate XVII.). The following results were obtained:—The machine with the cylinders at the base averaged a cut of 75 feet per week; and the machine, with the cylinders uppermost, averaged a cut of 93 feet per week. These lengths (cut when the machines were in full and constant work) fully demonstrated the extra speed of the latter machine, by reason of the easier removal of the coal from the front to the back of the machine. The cost, including everything, is a little above 3s. 4d. per foot. The contract price, paid to the men, was 1s. 8d. per foot, and the charter on the coal produced (a little over 2 tons per foot) was 1s. 8d. per ton. The district-price for driving this size of heading by hand is 7s. per foot, and the charter on the coal produced as before. The coal need not be taken into account in this comparison, being common to both machine and hand-heading. The distance cut by hand per week averages 45 feet. It is therefore apparent that the cost of the heading by these machines was less than half that of heading by hand, and (in the case of the machine with the overhead cylinders) the length cut was double that of hand-heading, in the same time.

The section (Fig. 8, Plate XVII.) of this heading shews that a band of very hard stone (Ryder stone) of an average thickness of 4 inches had to be cut. This retarded the cutting to a great extent, and the writer expresses his firm belief that, had it not been present, an average of 150 feet, or even more, would have been cut per week.

The experience with this latter machine (with overhead cylinders and drive) demonstrated more than ever the fact that, in order to increase the distance cut, it was necessary to improve further the facilities for removing the coal from the cutting. This has now been done to a much greater extent than before by the application of either a band-conveyor, or a trough-conveyor with scrapers (whichever best suits the special circumstances of any particular cutting), either of which practically performs this work automatically, and reduces hand-labour to a

minimum. The band-conveyor (Figs. 6 and 7, Plate XVII.) consists of a composition-belt, R, about 1 foot 9 inches wide, running on rollers or drums, placed about 7 feet apart, the front one being 6 inches in diameter and the back one 10 inches in diameter. The belt is kept tight by means of screw-carriages, O, operating on the back-end drum. It is driven by two sprocket-wheels, N_1 and N_2 on the shaft N, and a chain, N_3, these in turn being driven from the side-shaft of the machine by worm-and-bevel gearing: M is the worm; M_1, the clutch; M_2 the worm-wheel; M_3, the shaft; M_4, the bevel driving wheels; P and P_1, the shafts carrying the conveyor-belt drums; Q, bearings to carry the front drum-shaft; S, side-plates to retain the coal on the conveyor; and T, side-plates to pass the coal over, if desired. By varying the sizes of the gear and chain-wheels, the speed of the conveyor can be regulated to suit practically all circumstances. The inclination of the belt can also be varied by means of the sliding bracket, and the conveyor can be extended some distance further back from the machine, and at a greater inclination, so as to deliver the coal directly into a tub, thus saving it from having to be handled at all at the back of the machine. In cutting downhill, at a steep angle, the conveyor-band can be fitted at intervals with angle-iron ribs, so as to prevent the coal from rolling back to the face of the heading. This conveyor has not been practically tested in the mine; but, when this takes place, the writer will furnish a supplementary account of the results obtained.

The double machines, for a cut 9 feet wide and 5 feet 4 inches high, are fitted with cylinders, 10 inches in diameter and of 9 inches stroke. The speed of the engine varies from 160 to 200 revolutions per minute, the horsepower varying from 20 to 23. The gearing ratio is 24½ to 1, that is, the engine makes 24½ revolutions to 1 of the cutting arm. The piston-speed is usually about 240 feet per minute, and there are three threads to the inch on the main centre-shaft or feeding screw.

The length of the machine from the back gear to the front wings is 8 feet 4 inches; the width of the machine is 5 feet; the length of the centre screw-shaft is 10 feet 9 inches; and the total weight of the machine, including the conveyor, is a little over 6 tons. The different parts are easily detachable for removal, and the machine can be readily rebuilt in a new position.

The gear-wheels are made of crucible cast-steel; and the cranks, shafts, and main centre-shaft are made of best mild steel: the feed-nut for the last-named being of gun-metal.

The width of the groove cut by the double machine is about 4 inches, and the depth is 2 feet. The coal, however, generally begins to fall off when the groove is cut into a depth of about 9 inches. For use in tough seams, the wings have been made to cut to a depth of 3 feet. There are three cutters (each chisel-shaped) on each wing; and, when working in coal only, a length of 30 feet is often cut without having to change the cutters.

An air-pressure varying from 30 to 50 pounds per square inch is required at the machine for successful working, varying, of course, with the hardness of the material to be cut; and in soft coal, a pressure of 25 pounds at the machine will suffice.

The following diameters of pipes are recommended for carrying the compressed air to the double machines:—300 feet from the air-compressor, 2½ inches; 1,000 feet, 3 inches; 1,500 feet, 3½ inches; and 3,000 feet, 4 inches.

In all, eleven double machines have been constructed, all driven by compressed air; and, as regards electric driving, the double machine is much more convenient for its application than the single one. About a year ago, a double machine was made for a cut 8 feet wide and 4 feet high, and fitted with a three-phase motor of 30 horsepower, but it has not yet been tried in actual work. It must, however, be borne in mind that, in driving electrically, single headings would require to be ventilated, or two headings driven with slits between them, as in heading by hand.

The advantages gained by the use of these machines are as follows:—The heading is done in much less time than by hand, and at a much less cost. The workings are opened out quickly, in one-fourth of the time entailed by the use of hand-labour. No explosive is required in most cases. A much larger proportion of round coal, 70 to 80 per cent., is produced, than in hand-heading. There is a great saving in timber. The machine ventilates its own heading for long distances. The roads stand well, being unshaken by explosives, and are driven straight and smooth, thus offering little resistance to the ventilating current. The motive power, compressed air, makes the heading cool and

fresh. The driving of counter-headings and thirls is avoided to a great extent. No rails are required for the machine. The roads are easily turned in any direction, and the machines will work either to the rise or to the dip. The machines combine economy, efficiency and safety, and, in suitable seams, give great satisfaction: the better the seam the greater is the satisfaction given over hand-heading, and the machines will quickly pay for themselves. For special work, they can be constructed of any required strength, and capable of cutting through any material through which it is possible for steel to cut. Skilled labour is not necessary.

APPENDICES.

I.—NOTES OF PAPERS ON THE WORKING OF MINES, METALLURGY, ETC., FROM THE TRANSACTIONS OF COLONIAL AND FOREIGN SOCIETIES AND COLONIAL AND FOREIGN PUBLICATIONS.

PALLADIUM AND PLATINUM IN BRAZIL.

Ueber das Vorkommen von Palladium und Platin in Brasilien. By EUGEN HUSSAK. *Sitzungsberichte der Kaiserlichen Akademie der Wissenschaften, Wien,* 1904, *vol. cxiii., pages* 379-466, *with* 2 *plates and* 6 *figures in the text.*

A century has gone by since Dr. W. H. Wollaston announced the discovery of native palladium in the platiniferous and auriferous placer-deposits of the Serra do Espinhaco, and now the present author records the occurrence of the metal in the native state in the itabirites of Itabira do Matto Dentro. Far more frequently, however, does palladium occur in Brazil in the form of an alloy with gold, as, for instance, at the Gongo Socco mine, and in the contact-altered limestone of Candonga, Minas Geraes. The percentage of palladium in this alloy varies from 5 to 8. Besides giving copious extracts from the earlier literature, the author describes the results of the careful mineralogical and chemical investigation which he conducted on Brazilian specimens obtained in 1900 from the Munich and Vienna museums. The Candonga mine is now abandoned, although it seems to have been actively worked, or at least explored, for gold at one time. Palladium-gold, of a pale copper-red colour, has also been traced in the tailings from the Itabira-do-Matto-Dentro mine (now closed on account of inflows of water and other difficulties). Besides the copper-coloured variety, there is a rarer dark-brown gold, rich in palladium, and further an almost silver-white gold similarly rich in palladium.

The occurrence of these native alloys had not until quite lately been recorded from any other country than Brazil, but palladium is now said to have been found associated with the gold of certain Russian placer-deposits.

The existence of native platinum in some of the Brazilian gold-placers was known as long ago as 1801, but probably at that time palladium-gold was often mistaken for platinum. The researches carried out during the last 30 years have lengthened greatly the list of Brazilian localities for platinum. That found in the rio Abacte and its left-bank tributaries, probably derived from peridotites, is strongly magnetic, contains much iron, and is free from palladium. The platinum from Conceição and that from Condado, Serro, is in both cases non-magnetic, but the latter variety is rich in palladium, while the former is free from it. Along the eastern slopes of the Serra do Espinhaco platinum occurs in association with diamonds, derived from conglomeratic quartzites, but in such singular shapes that it must have been redeposited from solution—the outcome probably of the decomposition of platiniferous pyrites (such as are known to occur in the United States and Norway). Platinum has also been found in the auriferous quartz-veins which traverse the crystalline schists of the rio Bruscus, Pernambuco.

L. L. B.

ORE-DEPOSITS OF ORURO, CHILE.

Memorandum sobre el Mineral de Oruro. *By* CARLOS G. AVALOS. *Boletin de la Sociedad Nacional de Mineria*, **1904**, *series* **3**, *vol. xvi.*, *pages* **311-315**, *with* **1** *figure in the text.*

This district furnishes an example of those rare cases where the ancient traditions of mineral wealth are found to hold good even in our own day. Silver-ores were mined there long before the Spanish *conquistadores* set foot on American soil, and during the seventeenth and eighteenth centuries Oruro disputed with Potosí the silver-mining primacy of the world. Then the industry decayed, only to be revived in 1868. Between that year and 1886 the single mine of Atocha produced 174 tons of silver, and neighbouring mines in proportion.

The greatest depth to which the workings have been carried so far does not exceed 1,300 feet, and as the eruptive rocks with which the metalliferous veins are chiefly associated continue in depth, the author holds that a brilliant future awaits really deep-level workings. He points out that, in Pulacayo, mining has been pushed down to a depth exceeding 2,300 feet, without any noticeable impoverishment of the metalliferous veins, and he adduces similar examples from analogous silver-bearing deposits in Bolivia.

The Oruro veins are mineralized with invariably argentiferous pyrite and with masses of tinstone and quartz. In the Socavon-de-la-Vírjen mine, the proportion of silver amounts to 1 per 1,000, and that of tin to 5 or 8 per cent. of the crude ore; but there are richer portions of the deposit containing as much as 1 to 5 per cent. of silver. Since 1898, great progress has been made in the chemical treatment of the ores by the lixiviation-process (as practised in the United States and Mexico), but the mechanical part of the treatment is still capable of improvement. The amount of ore in sight, containing the smaller percentages mentioned above, is estimated at many hundred thousand tons, and the author calculates the probable net profit at about 30 per cent. L. L. B.

MINERAL RESOURCES OF CHIAPAS AND TABASCO, MEXICO.

Recursos Minerales y Aguas Minerales de Chiapas y Tabasco. *By* EMILIO BÖSE. *Boletin del Instituto geológico de México*, **1905**, *No.* **20**, *pages* **70-75**.

But few data are forthcoming on this subject, and so far the only mine that is permanently at work anywhere in the two states is that of Santa Fé, in the department of Pichucalco. The principal ore here is an auriferous and argentiferous bornite, with which are associated the decomposition-products, malachite and azurite. Around Santa Fé are various other occurrences of copper- and iron-ores, but nothing apparently is known as yet in regard to their industrial importance. South of Ocozucuautla, exploration-work has been done on the bornite-mine of La Alicia, and in the district of Tonalá, there is yet another copper-mine, known as La Aurora. From the neighbourhood of Las Chicharras, Tapachula, the author received specimens of bornite, native copper, galena, limonite and pyrites. In the northern portion of the Sierra Madre, and in various other localities, silver-ores are known to occur; and a small quantity of native gold is found in all the streams and rivers that run down from the Sierra Madre, but no single instance of a gold-washing can be cited. Hæmatite has been found near San Cristóbal, and magnetite, as well as kaolin on La Razón farm, in the

Cintalapa district. Native sulphur, deposited from thermal springs, occurs in small quantity in various localities of the state of Chiapas.

Lignite-seams occur in the Tertiary beds, but they are of small importance. Bitumen is of very frequent occurrence in both the states of Chiapas and Tabasco, though largely in districts that are still unexplored, geologically speaking. In many cases, it is regarded by the author as being one of the products of petroleum, which latter is found all along the northern border of Chiapas, and in the Macuspana district of Tabasco. In the last-named area, boring operations were being carried on at the time of writing. A fossil resin, simulating amber, occurs in small quantity in the Simojovel district of Chiapas, and appears to fetch a high price, in view of its utilization for the manufacture of fancy goods.

A fine, easily worked ornamental marble is furnished by some of the Cretaceous limestones, and pottery-clays occur all over the country, especially in the region of the Tertiary marine deposits. The dolomites of Chiapas would provide excellent road-metal if worked for that purpose: at present, such roads as do exist are very bad. Certain mineral-springs in the same state are of importance, on account of the large percentage of salts which they contain. In some cases, artificial heat is used to evaporate the water, in other cases the direct heat of the sun's rays is found sufficient. Sulphurous thermal springs are also fairly numerous. On the whole, the two states will probably derive their future prosperity from the agricultural, and not from the mining industry. L. L. B.

MERCURY-ORES OF CHIQUILISTLÁN, JALISCO, MEXICO.

Descripcion de los Criaderos de Mercurio de Chiquilistlán (Jalisco). By JUAN D. VILLARELLO. *Memorias de la Sociedad científica "Antonio Alzate,"* 1904, *vol. xx., pages* 389-397.

In his preliminary remarks, the author points out that the failure, which has so often dogged the endeavour to work at a profit such mercury-ore deposits as exist in Mexico, is not due to the supposedly-low grade of these ores, but to the often primitive and always wasteful processes of extraction applied to them. As a matter of fact, he claims that the average assay of the Mexican ores will bear comparison with those of Almaden, Idria and Huancavelica.

The deposits to which he calls attention in this memoir occur between the villages of Tapalpa and Chiquilistlán, in the state of Jalisco, 118 miles south-west of Guadalajara, in somewhere about 20 degrees of north latitude, and 5 degrees of west longitude (of the capital city of Mexico). The nearest railway-stations are distant about a day's journey on horseback. In 1843, a company began working the deposits, but suspended operations in the following year; since then various isolated, spasmodic attempts have been made to work some of the mines, but now a new company is about to re-open the workings on a fairly large scale. They occur at the foot of a sierra, which ranges south-eastward and north-westward: the slopes are forest-clad, watered by perennial streams, and the climate is healthy and temperate. The ores are chiefly found at the meeting-points of the fissures which traverse in all directions the hard, grey, Middle Cretaceous limestones of the district; these limestones are in places overlain by comparatively thin sandstones, clays and marls. Eruptive masses of hornblende-andesite bear witness to the volcanic activity which prevailed in Tertiary times, after the deposition of these sedimentary beds.

The general structure of the region is monoclinal: there are no great faults or fracture-lines; but the horizontal thrust which folded the limestones determined a series of "conjugate fractures" normal to its direction and parallel to the axis of upheaval, as well as (in combination with lateral pressure) another system of fractures perpendicular to those above mentioned. These fractures have not displaced the rocks sufficiently in the Chiquilistlán district to be dignified with the appellation of "faults." The first system of fissures, contemporaneous with the andesitic eruptions, allowed of the downward percolation of the surface-waters into the limestones, as well as of the upward percolation of thermal waters carrying metalliferous particles in solution. The fissures are mineralized with cinnabar, azurite, malachite, chalcopyrite and limonite, associated with calcite and a little gypsum. There is no banding such as to indicate various periods of deposition, or anything to show that the deposits have been subjected to movement since the original infilling. The average percentage of metallic mercury contained in the ores is 0·80.

Occasionally the deposits assume the form of strings of pockets, simulating true beds by their horizontal extension. The distribution of the ores appears to have been conditioned by the physical character, rather than by the chemical or mineralogical composition of the country-rock. The thermal waters appear to have enlarged the original cavities in the rock, and to have largely deposited their metalliferous constituents by metasomatic replacement: these were precipitated as sulphides, partly altered later on, by the action of the downward percolating surface-waters, into carbonates and oxides. Much exploration-work remains to be done, but the author regards the prospects which await judiciously-conducted mining operations as highly favourable. L. L. B.

IRON-ORE DEPOSITS OF THE CARRIZAL, COAHUILA AND NUEVO LEON, MEXICO.

Los Yacimientos de Fierro del Carrizal, Estado de Nuevo Leon. By GUSTAVO DE J. CABALLERO. *Memorias de la Sociedad científica "Antonio Alzate,"* 1905, *vol. xxii., pages* 183-186.

The Carrizal is a small sierra trending from north-west to south-east along the border between the states of Coahuila and Nuevo Leon, rather more than 6 miles west of Golondrinas, a station on the National railway-line. The iron-ores are intercalated between a poorly fossiliferous Cretaceous (?) limestone and a diorite, which forms part of the eruptive series of the district. This series, in addition to diorites, includes diabases and porphyrites, all more or less ferruginized at the surface. The limestones are the predominant rocks of the region, and vary in character and colour from black marble to green and red marly stone. So far as they have been laid bare, they fail to exhibit any considerable folding. Geodes lined with garnet-crystals occur frequently at the contact between the iron-ore and the limestone. The ore is traced all round the sierra, at an altitude of about 2,000 feet above sea-level, in the form of a reef varying in thickness from 6½ to 26 feet or more. It consists chiefly of oxides of iron with which are associated limonite, marcasite, iron- and copper-pyrites, etc., while hæmatite occurs more especially at the contact with the diorite.

The author describes some of the more interesting mineral-specimens obtained from the reef, including a piece of fossil wood metamorphosed into

magnetite, still showing the rings of growth and portions of bark. Typical samples of ore have yielded the following analyses: hæmatite, 69·2 per cent. of iron and 30·6 of oxygen; magnetite, 72·1 per cent. of iron and 17·2 of oxygen; pyrites, 46·2 per cent. of iron and 52·9 of sulphur.

West of the sierra is a valley, some 25 miles broad, in which is an ancient crater, known as El Volcán; the basalts, trachytes, pumice, and obsidian associated with this ancient crater extend up to the slopes of the Carrizal. Seeing that these rocks cover in part the Quaternary deposits, the crater must have been active at a comparatively recent date. The diorites, on the other hand, which traverse, dislocate, and marmorize the Cretaceous limestones are probably of Upper Cretaceous age, and with them we may perhaps associate the genesis of the ore-deposits.

L. L. B.

SANTIAGO Y ANEXAS GOLD- AND SILVER-MINES, MICHOACÁN, MEXICO.

Descripcion de las Minas "Santiago y Anexas" del Estado de Michoacán. By JUAN D. VILLARELLO. *Memorias de la Sociedad científica "Antonio Alzate,"* 1905, *vol.* xxii., *pages* 125-140, *with* 1 *figure in the text and* 3 *plates.*

The mining concessions of the Santiago y Anexas Company are situated among the hills of San Martin, Palo Gacho, and La Peña, some 3¾ miles south-west of Tlalpujahua, in the Maravatío district of the state of Michoacán, and were visited by the author about the middle of the year 1899. From El Oro, whence there is a branch-line to Tultenango on the National railway, it is a 2¼ hours' drive by road to the mines.

The oldest rocks of the district are the Cretaceous black clay-slates and limestones, highly contorted, fractured, and dislocated, with a general westerly dip. They are cut off and, in places, overwhelmed by andesites, of which the author distinguishes two varieties: (1) an intrusive rock, occasionally silicified by the action of thermal waters in the neighbourhood of the metalliferous veins; and (2) an effusive rock, petrographically similar to the intrusive, occupying a considerable superficial extent, of extremely variable thickness, and much broken up by weathering. Of later date than the andesites are the rhyolites and rhyolitic tuffs, the last-named of which in part mantle over all the previously-mentioned rocks. No strictly sedimentary deposits of later date than the Cretaceous occur hereabouts, except those derived from the disintegration of the aforesaid rocks, which have been laid down in depressions of the surface. Hence it is inferred that ever since the time of the folding of the Cretaceous slates, etc., the country has been dry land.

Three principal fault-systems are recognizable, in two of which the fissures are nearly vertical, while in the third case they have a variable dip to the westward. Two of these systems, cutting each other obliquely, date from before the eruption of the andesites (Miocene?), and are themselves dislocated by the later (Pliocene?) system of faults which traverses both the andesites and the Cretaceous clay-slates. The fissures vary somewhat in breadth, and so the mineralization rather presents the appearance of a series of lenticles sometimes isolated, and sometimes connected by thin and sinuous "stringers." The vein-stuff may be described as a breccia, and on the whole the average thickness of the veins is stated at 16 inches. Locally the term *mantos* or seams is applied to the deposits formed from

the weathering of the outcrops of the metalliferous veins: these débris together with fragments of slate have been laid down in neighbouring depressions of the surface. The *mantos* contain a certain proportion of free gold, and in the rainy season a small quantity of the precious metal is collected from the streams which flow west of the Santiago mine. The primary ore is pyrites in a gangue of quartz, and the secondary ores are iron oxides, together with native gold and native silver in large grains. Enrichment in the neighbourhood of the intersection of the two older systems of fissures is a noticeable feature. There seems to be little doubt that the mineralization of these fissures is due to the percolation of thermal waters, the origin of which is not unconnected with the vulcanicity represented in part by the intrusion and effusion of the andesites. When, as a consequence of organic movements, etc., the later fissures were opened up, there was again an upward percolation of thermal waters, containing, however, much less gold than the older mineralizing solutions. Assays are tabulated of ores taken from the Dolores, Animas No. 1 and No. 2, Murciélago, La Luz, Santa Cruz, and other veins, and from the *mantos*. The maximum amount of gold obtained from any of these samples is 68½ parts per million, and of silver 226½ parts per million (say 2·20 and 7·25 ounces Troy respectively per metric ton), and the average amount is 10 parts per million of gold and 33½ parts per million of silver (0·32 ounce and 1·07 ounces respectively per metric ton).

A short description is given of the various workings, many of which were abandoned and had fallen in at the time of the author's visit. On the whole, it cannot be said that much exploration-work has been done on the veins of this district, and mining operations have been of a superficial, and in places of a wasteful character. The clay-slates form so insecure a country-rock, that timbering is a necessity. Fortunately, timber is easily procurable locally and is also cheap. The permanent water-level of the country is only 180 feet below the surface, and the continuance of mining operations involves drainage of the water at the rate of 66 gallons a minute, a quantity which increases *pari passu* with the depth. Labour is abundant and by no means dear. The climate is healthy and pleasant, and there are waterfalls capable of furnishing power. That of Labastida is already in part so utilized.

The Juana-de-Arco works for the treatment of the ores are situated some 2½ miles south of the Cerro San Martin, and communicate with the mines by means of a broad road suitable for wheeled traffic. The stamp-batteries can deal with about 30 tons of vein-stuff daily. There are six electroplated amalgamators, and the entire plant is set in motion by a Pelton wheel. A well-equipped assay-office is attached to the works. The assays show that, by the system of amalgamation without the use of heat or any chemical, in vogue at Juana de Arco, only 50 per cent. of the silver and 55 per cent. of the gold are got out of the ore. Cyaniding has not as yet been tried there. L. L. B.

IRON-ORE DEPOSITS OF TATATILA, VERA CRUZ, MEXICO.

Los Yacimientos de Fierro de Tatatila. *By* ALBERTO CAPILLA. *Memorias de la Sociedad científica "Antonio Alzate,"* **1904, *vol. xix., pages* 341-346.**

These deposits occur in various ravines running down from the great central plateau, in the canton of Jalapa, in the state of Vera Cruz. The country is very broken, constantly veiled in thick mists, and watered

by abundant rains, discharged by the winds blowing in from the ocean as they beat against the scarps of the central plateau.

The most actively worked deposit is that of La Providencia, whence the ores are carried by a recently completed wire cable-way to the terminus of a branch railroad, which connects with the main Interoceanic railway at the station of Las Vigas (8,036 feet above sea-level). The cable raises a maximum of 30 tons of ore per hour to a great 500 tons tippler, whence the stuff can be tipped direct into the railway-trucks, and thus the total cost of transport to Las Vigas is very low. The scarcity of water for industrial purposes at that locality accounts for the establishment of the smelting-works elsewhere, at Tepeyahualco, 31 miles distant, on the same line of railway.

The great number of outcrops of ore of identical composition originally led prospectors to imagine that the entire mass of the Providencia ridge was built up of iron-ore, and to estimate the amount in sight at many millions of tons. As a matter of fact, the ore-deposit consists of a number of contemporaneous dykes which traverse, and at the zone of contact have marmorized, the Middle Cretaceous limestone that forms the greater part of the massif. The dyke-rock is defined as a quartziferous biotite-diorite or tonalite, containing oxides of iron and pyrites. In some places, there are also outcrops of labradorite-gabbro and pyroxene-dacite.

The iron-ore has been separated out by magmatic differentiation, forming thick bands or reefs (maximum thickness, 60 feet) between the tonalite and the marmorized limestone. Its specific gravity is 4·9, it contains in selected specimens 63 per cent. of metallic iron, 2·7 per cent. of sulphur, 1·5 per cent. of silica, and 0·9 per cent. of manganese; and it is described as a hæmatite with a small admixture of magnetite, mica and iron-pyrites. Nests of biotite-mica occasionally occur in the mass of the ore. Taking all the grades of ore into consideration, the true average percentage of metallic iron would hardly exceed 55. The immediate probable output from La Providencia alone is about 200 tons per day, but it was expected that this would be doubled in the course of six months.

What the author says in regard to La Providencia, is also applicable, he thinks, to the neighbouring deposits of Santa Ursula, Los Palacios, Granadina, etc.; and, when all these are regularly worked, they will doubtless form a very important factor in the development of the iron-industry of Mexico. L. L. B.

MINERAL RESOURCES OF THE PROVINCE OF CAJABAMBA, PERU.

La Provincia de Cajabamba y sus Asientos minerales. By FERMÍN MÁLAGA SANTOLALLA. *Boletín del Cuerpo de Ingenieros de Minas del Perú,* 1905, *No.* 19, *pages* 1-90, *with* 1 *figure in the text,* 7 *plates and a map.*

This province forms the southern portion of the department of Cajamarca, and its capital city (of the same name as the province itself) lies at an altitude of 9,370 feet or so above sea-level, in 7 degrees 30 minutes 50 seconds of latitude south, and 80 degrees 31 minutes 20 seconds of longitude west of Paris. The climate is extremely salubrious and equable, and the province is traversed from north to south by the Western Cordillera of the Andes. The streams and rivers all flow ultimately into the Crisnejas, which is a tributary of the great rio Marañón. At present, the nearest railway-station is Trujillo, at least 110 miles distant by various roads from Caja-

bamba; but from Trujillo to the harbour of Salaverry, on the Pacific seaboard, the distance is only 9¼ miles. There is telephonic communication between Cajabamba and Trujillo, among other places.

Geologically the province consists of a great sedimentary system, made up of limestones, shales, sandstones, and the corresponding conglomerates: these take up the entire area, with the exception of a great trachyte-dyke which enters the province from the south and ranges through it for about 19 miles, terminating in the southern flank of the mountain of Algamarca, on the right bank of the rio Chimín. The orogenic movements connected with the uplift of the Andes have greatly plicated and contorted the stratified rocks, and fissured them in many places as well. Many of these fissures have been subsequently infilled with metalliferous ores. The trachytic eruption is shown to be of more recent date than these phenomena, and dykes originating from it cut the metalliferous veins at right angles; moreover, the veins have in places been faulted by the movements resulting from the eruption. The age of the stratified rocks, according to the available palæontological evidence, ranges from Neocomian (or Infra-Cretaceous) to Supra-Cretaceous.

In addition to native silver, the ores which occur in the mineral-veins are chiefly argentiferous sulphides of antimony, copper, zinc, iron, lead and arsenic. The mineralization is not of the same character throughout the province, but the veins of Algamarca may be regarded as classic examples; and there the Descubridora vein, for instance, has a uniform thickness and yields an average assay of 6½ dwts. of gold, 160 ounces of silver, and 14 per cent. of copper per metric ton. In the veins of Capán, Cochas, and Sayapullo, the mineralized zones alternate with barren zones, and they are as variable in thickness as in quality. The metalliferous particles were evidently deposited by hydrothermal action: at Algamarca, the waters percolated from below upward, but in other districts there was also a secondary concentration or enrichment, due to the downward percolation of meteoric waters. Proceeding to the detailed description of the deposits, the author points out that gold in the free state does not occur in the province, but where it is found in the metalliferous veins, it is combined with other minerals.

At Algamarca, the daily output of ore amounts only to 2 tons, the number of persons employed at the mine being 47 all told. The amount of ore in sight would, however, justify the sinking of sufficient capital to conduct operations vigorously on a large scale. Much the same may be said of the Sayapullo deposits, but those of Cochas are of small industrial importance.

Intercalated among the shales which alternate with the sandstones of the great sedimentary series are sundry coal-seams which crop out at the surface at various localities in the Condebamba river-basin. They range in thickness between 1½ and 2½ feet, and exhibit different physical properties: thus, in the north-west, the coal is crumbly and schistose, while in the south-east it is tough and compact. The following are typical analyses of the respective varieties:—

	North-western Coal-seam. Per cent.	South-eastern Coal-seam. Per cent.
Fixed carbon	57·34	83·74
Volatile matter	19·56	6·80
Hygroscopic water	3·10	4·30
Ash	20·00	5·16
Heating power	6,629 calories	7,708 calories

These coals both belong to the same geological formation, but the south-eastern coal-seam has undergone a sort of natural distillation, due to contact-metamorphism set up by the great trachyte-dyke previously mentioned. The north-western coal-seam is unsuitable for industrial purposes, owing to its excessive pulverulence: kneaded up into balls with 10 to 15 per cent. of plastic clay, it furnishes a fuel of very middling quality.

The coal-bearing belt extends within the province of Cajabamba for some 10 miles from north to south, and it has been traced beyond that southward and south-westward into the neighbouring provinces of Huamachuco and Otuzco.

The author describes the various methods of working the metalliferous mines adopted in Cajabamba, and one gathers that, on the whole, they are very old-fashioned, not to say primitive. Both the ore and the waste are brought to bank on the miners' backs; and the inclination of the galleries is so very steep, that these would have to be remodelled before tram-rails could be laid down in them.

With regard to the treatment of the ores, they were, from 1899 until May, 1904, sent to the lixiviation-works of Araqueda, rather more than 9 miles by a good cart-road from the Algamarca mines. Since then, the former difficulties in regard to fuel having been overcome, recourse has once more been had to reverberatory furnaces.

The author considers that a prosperous industrial future awaits the province of Cajabamba, in view of the fertility of its soil, the diversity of its products, the abundance of its water-supply, the equability of its climate, the wealth of its mineral resources, and the plentiful amount of labour which is available. It should be noted that, in addition to the ore that is still unworked, a vast mass of old tailings in the Sayapullo mines would repay working. The two great needs are the provision of a system of good roads, and the influx of judiciously applied capital. L. L. B.

MINERAL RESOURCES OF THE PROVINCE OF CAJATAMBO, PERU.

La Provincia de Cajatambo y sus Asientos minerales. By FERMÍN MÁLAGA SANTOLALLA. *Boletín del Cuerpo de Ingenieros de Minas del Perú*, 1904, *No.* 10, 80 *pages, with* 2 *figures in the text,* 3 *plates, and* 1 *map.*

This mountainous province occupies an area of 1,936 square miles between 10 degrees 57 minutes and 10 degrees 10 minutes of latitude south, and between 78 degrees and 79 degrees 56 minutes of longitude west (of Paris). It is estimated that the population amounts to about 30,000, spread along the banks of the rivers, the three principal of which are the Pativilca, Supe, and Huaura, all, of course, debouching into the Pacific ocean. The climate is variable but, on the whole, healthy. There is a well-marked season of rains (from October to April) and a dry season (from May to September). At such localities as Chanca and others, 16,000 feet or more above sea-level, the precipitation of water is generally in the form of snow or hail.

Apart from mining, the principal industry of the province consists in rearing sheep and cattle, which are sent down to the coast. Cereals and other provisions are dear, although they could be easily raised in the province itself, if the inhabitants were less afraid of work than they generally are. The distances westward by road, to the harbours of Supe and Huacho on the Pacific seaboard, are respectively 103 and 112 miles; and eastward

to the famous mineral-district of Cerro de Pasco, 73 miles. Concessions have lately been granted for the construction of railways, which will soon become a potent factor in the economic progress of this region.

The formations of which it is built up are limestones, sandstones and shales, with associated coal-seams, highly folded and dislocated by the earth-movements which originated the upheaval of the main Cordillera; amid them eruptive bosses of porphyry and diorite rise, forming the isolated links of a broken chain, generally aligned south-south-east and north-north-west, that is, parallel with the main axis of upheaval, at a distance of 18 miles or so from it.

The useful minerals include native gold and silver, ores of silver, copper, lead, zinc, iron, manganese, antimony and arsenic (the sulphidic ores are generally auriferous); also native sulphur, graphite, and coal of various types. The mining district of Chanca (15,500 feet above sea-level), 12½ miles distant from the provincial capital, Cajatambo, has long been famed for its metalliferous veins: these represent the outcome of the precipitation which took place, ages ago, from thermal waters percolating through the fissures in the eruptive rocks of which the mountain-ranges thereabouts are built up. The infilling (counting from the centre towards the sahlband) generally consists of symmetrically-disposed bands of pyrargyrite and tetrahedrite-spangled quartz or calcite, followed by bands of fine or coarse-grained pyrite (the former being richest in silver), then again by quartz or calcspar, and finally by thick bands of pyrite. To these, in some cases, must be added bands of galena, blende and chalcopyrite, so that the total thickness of such a vein may exceed 40 inches. Such working as has been done on the Chanca metalliferous deposits hitherto has been unsystematic, not to say wasteful and improvident. There is an enormous deposit of galena in the Raura district, the importance of which is enhanced by the vicinity of good coal-outcrops. A brief description is also given of the ores of the districts of Quichas, Uchush-Chacua, Izgues, Pomahuain, Auquimarca, etc.

The existence of coal in the province of Cajatambo has been known for about a generation, and coke was made from it and applied to industrial purposes as long ago as 1881; but the true extent and value of the outcrops has only been ascertained quite recently, that is, in 1903. No time has been lost since then in obtaining concessions from the Peruvian Government for the construction of railways which are destined to open up the new coal-fields. It may be said that throughout the province wherever the sandstones are exposed, there too the coal-seams and the associated shales crop out; from north to south the coal-bearing belt stretches for 50 miles, and beyond that into the province of Chancay; while its breadth from east to west, from the Cerro de Pasco to Andajes, exceeds 30 miles. Owing to the high dip and compressed folding of the strata, the mass of coal in places attains a gigantic thickness, being built up of seams which may be anything from 16 to 260 feet thick, separated by very thin partings of shale and sandstone. In the vicinity of the eruptive massifs, the seams are anthracitized, but farther away from these massifs (as at Conocpata, Saquicocha, etc.), the average character of the mineral is illustrated by the following analysis:—Fixed carbon, 67 per cent.; volatile matter, 25 per cent.; hygroscopic water, 4 per cent.; ash, 4 per cent.; heating power, 6,505 calories. With this may be compared an analysis of the anthracite: fixed carbon, 79 per cent.; volatile matter, 9·8 per cent.; hygroscopic water, 3·2 per cent.; ash, 8 per cent.; and heating power, 7,371 calories. Excellent

coke is yielded by the bituminous coals of Saquicocha. At Andajes, a coal, which in character lies midway between these and the anthracites, contains less volatile matter than the former, burns with a shorter flame, and yields a heavier coke.

The coal-seams of Oyón are worked on a small scale, in the south-eastern district, nearest the great mining region of the Cerro de Pasco (31 to 37 miles distant), whither the soft coke (obtained by burning small hillocks of coal, much after the primitive fashion in which native sulphur was roasted in the open at one time by the Sicilian miners) is taken by pack-llamas. Even so, the coke obtained in this rudimentary fashion, is of sufficiently good quality.

In conclusion, the author opines that there is enough excellent coal in sight, in the province of Cajatambo alone, to supply the needs of the entire continent of South America for years to come, and to shut out completely the further importation of European or other foreign coal.

A description is given of the smelting-works of Gasuna, Quichas and Otuto, and an alphabetical index of place-names facilitates reference to a carefully compiled memoir such as this is. L. L. B.

MINERAL RESOURCES OF THE CHACAS AND SAN LUIS DISTRICTS, HUARI, PERU.

Recursos Minerales de los Distritos de Chacas y San Luis. By ENRIQUE J. DUEÑAS. *Boletin del Cuerpo de Ingenieros de Minas del Perú,* 1904, *No.* 15, *pages* 1-142, *with* 21 *figures in the text and* 3 *plates.*

The districts dealt with in this elaborate memoir are situated in the province of Huari, which occupies an area extending from the summits of the Cordillera Blanca eastward down to the banks of the rio Marañón. The mineral-occurrences include auriferous quartz-reefs, gold-placers worked since time immemorial, veins of argentiferous galena and cupriferous ores, molybdenite, rock-salt, coal, graphite, kaolin, fire-clays, etc. Moreover, there is an abundance of a particular variety of timber, especially suitable for pit-props, etc., growing right up to the snow-line.

The district of Chacas is higher lying than that of San Luis, and consequently the climate is colder; the altitudes mentioned in the geographical description range from 10,000 to 15,000 feet above sea-level. From Casma, on the Pacific seaboard, by what is known as the "central route," the distance to Chacas is 120¼ miles; and, under favourable conditions, the up-country journey is performed in about 5 days. During the rainy season (from October to May) the roads, such as they are, lie in part under water or are mere stretches of swamp. Freights are consequently heavy, and the only method of transport is by pack-horse or pack-mule. It has not been found possible to acclimatize the llama in this part of Peru. About 15 pages are devoted to a description, both geographical and geological, of the "central route," from Puerto de Casma to Chacas, before the author plunges into *medias res*, namely, the petrology, stratigraphy and palæontology of the region.

The predominant rock exposed in the mountain-summits and at the heads of the valleys is a quartziferous hornblende-mica-diorite. Resting upon or abutting against this are seen bluish-black slates (which are, however, in many places highly metamorphosed, such varieties as quartz-schist, talc-schist, etc., being noted), seamed in every direction by venules

of milky quartz. Next above the slates or schists comes the sandstone-formation, the mass of which is fine-grained, ashen-grey, with an argillaceous cement: it is much altered at the junction with the slates. Locally, other varieties of sandstone are found, exhibiting differences in colour, structure, and composition. Among the sandstones, which, by the way, conformably overlie the slate-series, occur the celebrated coal-seams, and many thermal springs, which (at the surface) deposit limonitic iron-ore and calcareous tufa, can be traced to the same formation. The approximate total thickness of the slate-series is 14,000 feet; the general strike of all the sedimentaries is north-north-west and south-south-east, and the dip is northerly or north-easterly. Their age is considered to be Upper Liassic, between Sinemurian and Toarcian. The eruptive rocks (diorites, porphyries, and trachytes) are post-Cretaceous, with the exception of the granitic masses which seem to be at any rate pre-Cretaceous, if not Jurassic.

The rocks of the Chacas and San Luis districts are traversed in every direction by innumerable fissure-veins, among which three principal systems can be disentangled. In the first group, the ores (in order of abundance) are well-crystallized galena, yellow and black zinc-blende, stibnite in very fine needles, pyrite, erubescite (containing a good proportion of silver), and very rarely bournonite and mispickel. In the second group, galena is again the principal ore, but it is more markedly associated with cupriferous minerals, such as amorphous chalcopyrite. The galena is highly argentiferous. In the third group, most of the ores mentioned as characteristic of the first recur. The veins are equally well mineralized in the sedimentaries and in the eruptive rocks. A lengthy description is given of the principal metalliferous mines, and one gathers that, in many, the method of working is unsystematic and wasteful. Areas still unworked are undoubtedly rich in silver-bearing and even gold-bearing ores, but the industrial future of these deposits is intimately associated with a necessary reform in the methods of working.

The author then deals at some length with the coal-deposits of the Chacas and San Luis districts. The anthracitic formation extends right through these districts, from north to south, parallel with the main axis of the Andes. Contact-metamorphism, due to the eruptive masses which crop up in the middle of the sedimentary anticline, is held to be the cause of the anthracitization of the coal in this case; where the metamorphism has been most intense lenticles of graphite are observed, both among sandstones and among slates. Dr. Raimondi's analyses of the Uchusquillo and Archuay anthracites are quoted; the latter is very similar to that from the Plutón mine, analysed by the author, and yielding the following results: fixed carbon, 86·70 per cent.; volatile matter, 10·24 per cent.; ash, 3·06 per cent.; specific gravity, 1·6; heating capacity, 6,633 calories. The coal is lustrous, black, sometimes shot with grey, with conchoidal fracture, and specks of ochre. The Cuchiguaganam coal is of jet-like appearance, with occasional iridescence, irregular fracture, and very compact structure. It yielded to the author the following analysis: fixed carbon, 86·15 per cent.; volatile matter, 11·85 per cent.; ash, 2 per cent.; specific gravity, 1·5; and heating power, 6,670 calories. At the Vulcano mine, a seam of semi-anthracite, never less than 2½ feet and often more than 4½ feet thick, is worked: its average heating power is equivalent to 6,700 calories, it contains 85·44 per cent. of fixed carbon, 12·30 per cent. of volatile matter, and yields 2·26 per cent. of ash. The specific gravity varies between 1·72 and 1·65. On the whole, all these coals are comparable with those mined at Wilkesbarre

in Pennsylvania. Semi-bituminous and bituminous coals are not altogether absent from the Chacas and San Luis districts, but their occurrence is comparatively rare. At present, only two collieries are at work there (the Vulcano, previously mentioned, and the Proserpina y Plutón): the method of working is by pillar-and-stall.

A long chapter (35 pages) is devoted to a description of the present condition of the mineral and metallurgical industries in those districts. Of the total number of mines officially recognized, only about a quarter are being actively worked. The author thinks that the San Luis district will in the future derive its chief importance from coal-mining, and that metalliferous ore-mining, long decadent there, will never be revived on any considerable scale. It is otherwise with the Chacas district. Full details are given of the smelting-works situated in the Checchipampa valley (13,000 feet above sea-level), 6¼ miles distant from Chacas and about 125 miles from the Pacific seaboard. The products are chiefly pig-lead (containing a little gold, and much silver and copper) and copper-matte (containing 4 to 5 per cent. of silver and 30 to 36 per cent. of copper). The manner in which the ores got on the Pompei and Contadera estates are treated, is also described at length.

With regard to the future industrial prosperity of these regions, it is bound up with the provision of rapid and economical means of transport. Next in importance comes the question of labour-supply; and thirdly, the inflow of capital. The author designedly places this requisite last, as he does not agree with the endless repetition of the dictum that before everything the Peruvian mineral industry needs capital; he says, in effect: "let us but have roads and railways, and the rest will come of itself." He uses some very strong language in regard to the invincible laziness of the great mass of the population, and advocates the passing of laws which would make work obligatory. L. L. B.

COAL-DEPOSITS OF THE CHECRAS DISTRICT, CHANCAY, PERU.

Yacimientos carboníferos del Distrito de Checras. *By* E. A. V. DE HABICH. *Boletín del Cuerpo de Ingenieros de Minas del Perú*, 1904, *No.* 18, *pages* 1-32, *with* 10 *figures in the text and* 3 *plates.*

This district forms part of the province of Chancay, and the lowest altitude mentioned by the author is 10,000 feet above sea-level, the highest being apparently reached in the Cumbre de Yaru (19,024 feet). It is divisible mineralogically into two distinct areas: one comprizing the coal-belt, which stretches for at least 10 leagues (31 miles) from beyond Chiuchín to the villages of Puñun and Tongos; the other being the area of eruptive rocks with metalliferous deposits. From the harbour of Huacho, on the Pacific seaboard, to Parquín (within the coal-belt), the distance is 121 miles, a distance which, under present conditions, is generally covered in three days. From Lima, by a different road, it is a five days' journey.

Some of the best exposures of coal-seams are within the boundaries of the Parquín township: four seams can be traced thence south-eastward for a distance of 8 miles. In point of fact, coal-outcrops are traceable over double that distance. The author specially investigated the area (covering 40 square miles) comprized between the mountain-ridges of Polvorillo, Pucayacu, Yanamá, and Huancho. No. 1 seam shows a thickness of at least 13 feet of coal, dips 62 degrees, strikes north-east and south-west, and can be

followed up for 8 miles. No. 2 seam, also about 13 feet thick, 130 feet north-east of No. 1, strikes parallel with it, and dips 56 degrees. No. 3 seam, with a similar strike and a dip of 39 degrees, barely 33 feet north-east of No. 2, is about 5 feet thick. At Huancho, the thickness of No. 3 seam is found to have increased to 6½ feet or more. In some places the outcrops are masked by forest-growth, in others by the débris tumbled from the crests of the ridges, or by snow. But there is no question, either as to the general strike, or as to the existence of other seams besides those just described.

The coal-bearing formation, consisting of a succession of sandstones and shales, is underlain by diorite and overlain by dark-grey limestones full of characteristic Cretaceous fossils. All the stratified rocks of this region have been ridged up into enormous folds. In the shaly band which generally intervenes between a coal-seam and the sandstone, abundant impressions of a fern-like plant are found (*?Echinostrobus*).

It is estimated that water-power equivalent to 16,600 horsepower could be obtained at Parquín, by making use of the mountain-streams which flow through the neighbouring ravines. The amount of coal contained in the workable deposits is estimated by the author at 3,969,000,000 tons. At the outcrop, the mineral presents the characters of a soft, pulverulent anthracite, but it is much tougher directly one cuts into the seam below the surface. Analyses made of two specimens, obtained from a depth not exceeding 82 feet at Parquín, yielded the following average result:—Ash, 3·50 per cent.; fixed carbon, 83·70 per cent.; volatile matter, 8·05 per cent.; hygroscopic water, 4·75 per cent.; and heating capacity, 7,870 calories.

L. L. B.

AURIFEROUS DEPOSITS OF CONDESUYOS AND CAMANÁ, PERU.

Yacimientos auríferos de Condesuyos y Camaná. By LISANDRO U. ALVARADO. *Boletín del Cuerpo de Ingenieros de Minas del Perú*, 1905, *No.* 20, 49 *pages and* 5 *plates.*

The province of Condesuyos has for its capital Chuquibamba, and most part of it is at least three days' journey distant from the nearest harbour on the Pacific coast. The country is rugged and mountainous, and is watered by one important river, the rio de Ocoña, which will, sooner or later, be made available for motive power in connection with mining operations. The climate is, on the whole, of Andean character, that is, rather cold than otherwise. But that of the gold-mining district of San Antonio or Andaray, 2,755 feet above sea-level, is described as warm, and paludean fevers are endemic, the miners often being disabled by simultaneous attacks of tertian ague. The mines are 22 leagues distant from the Pacific seaboard, and the distance to be travelled is 62 miles or so, by heavy roads, in the opposite direction to Chuquibamba.

Mining operations, suspended since 1858, were actively resumed forty years later. The gold occurs in fissure-veins, some of which were initiated by the eruption of the columnar basalts, which, with the altered granites, make up most of the solid geology of the district. The infilling of the veins consists chiefly of quartz, pyrites, and a sort of consolidated clay derived from the decomposition of felspars. The basalts are overlain by lavas, tuffs and volcanic ashes, together with deposits of rock-salt and gypsum. At the present day, the district is still one of considerable seismic instability.

The author devotes some space to the description of Chira bay, a roadstead with a sandy bottom, but of comparatively exiguous dimensions, which he thinks will presently assume importance in connection with the traffic to and from the gold-mines of both the provinces dealt with here.

He then describes in detail the six veins which are now the property of the Sociedad Aurífera de Andaray. He says that exploration-work and forewinning, in the proper sense of the term, have so far been confined to the Mercedes vein. Here ten horizontal adits have been driven one above the other from the base of the mountain up to a height of 820 feet. " Horses " or barren areas are not infrequent, and the tenour in gold as well as the thickness of the vein is variable. It occurs native in the quartzose gangue, and also in combination with pyrites. Where the sulphides (invariably auriferous) have been decomposed to oxides, visible gold may be looked for; near the surface in fine spangles, and at 650 feet or more from the surface in grains and nodules. The workings are extremely dusty, and the miners suffer much inconvenience thereby.

In the Charhuani ravine, a tributary of the Chorunga ravine, wherein occur the veins just described, prospecting-work has been done on several very promising gold-quartz reefs; and the comparative proximity of the rio Grande, the principal affluent of the rio de Ocoña, is a favourable factor, on account of the water-power which could be made available for smelting-works, etc. Farther south, the auriferous veins of Huaca and Iquipi, which occur among the black columnar basalts of the Cerro de Yanacaca, are at present untouched. Turning north again, we come to the Mina del Rey, in the glen of Alpacay, where many varieties of gold-quartz are worked, among them one of an alabastrine whiteness, apparently barren, yet uniformly yielding from 0·384 to 0·480 ounce of gold per ton.

A description is given of the works where the output from the Mercedes mine of Andaray is treated, and a brilliant future is predicted for the gold-mining industry in the province of Condesuyos, provided the necessary capital is forthcoming, backed by adequate technical knowledge and administrative ability.

The coastal province of Camaná is then described. Cupriferous veins have been the object of prospecting-work in the ridges that abut on the Pacific in the vicinity of the mouth of the rio de Ocoña. Numerous gold-quartz reefs are known to exist, the richest of which occur in the Cerro de Posco, far inland, bordering on the district of Andaray. Capital is being sought, in order to work the Posco reefs on a large scale, and reasons are assigned for the expectation that the industry would prove highly remunerative. The results of various assays, made in 1896 and 1897, are tabulated, and it is estimated that £33,000 would represent the value of the output of gold for every 1,000 feet of reef worked. L. L. B.

MINERAL RESOURCES OF THE PROVINCE OF OTUZCO, PERU.

La Provincia de Otuzco y sus Asientos minerales. By F. MÁLAGA SANTOLALLA. *Boletín del Cuerpo de Ingenieros de Minas del Perú*, 1905, *No.* 22, 70 *pages, and* 4 *plates.*

This province, bounded on the east by the western Cordillera, the *divortium aquarum* between the Pacific and the Atlantic, with its capital city 51¼ miles distant from the coast of the former ocean, is in parts very mountainous. Its products are as varied as its climate, and, *mirabile dictu*, it is possessed of a network of fairly good roads (apparently not, however,

suitable for heavy wheeled traffic). Consequently the port of Truxillo can be reached in a day and a half's journey from the above-mentioned city of Otuzco.

The rocks which constitute the solid geology of the region are described at sufficient length, under the heading of (1) sedimentaries, including sandstones, conglomerates, slates, limestones and clays; (2) eruptives, including petrosiliceous porphyries, rhyolites, porphyrites and hornblendic granites; and (3) metamorphic rocks. The strike both of the sedimentary and the metamorphic formations throughout the province is east and west, but veers somewhat round to north-west and south-east on approaching the Cordillera; and the dip, variable in amount, is northward or southward according to which limb of the anticline the strata belong. Generally speaking, the northern portion of the province is occupied by sedimentary rocks, the central portion by the metamorphics, and the southern portion by the eruptives—but this must not be understood too literally. At Huaranchal, near Choquisongo, a chalybeate thermal spring issues from the sandstone at a temperature of 167° Fahr.

The useful minerals of the province are found in five districts out of eight, and include gold-quartz, native silver, silver-ores, copper-, lead-, manganese-, iron-, and antimony-ores, and anthracitic coal.

Near the northern border is the mining-district of Carangas, where the sedimentaries, folded and fissured in the process of uplift of the Andes, have been altered by contact-metamorphism due to the eruption of the hornblendic granites. A later infilling of these fissures has transformed them into a system of metalliferous veins, the principal and best explored of which is the Santa Catalina vein. The infilling, sulphidic where the vein traverses slates, is oxidic where it traverses sandstones, even at the same level, and the different permeability of the rocks makes this easily explicable. The metals hitherto extracted are gold, silver, and copper, and it would appear that the mere fringe of the deposit has so far been touched.

West of Carangas lies the mining-district of Malín, on the right bank of the rio de Huancay, within comparatively easy reach of the railway that runs to Truxillo and Salaverry. Here the fissures, which were opened up in every direction in the sedimentary rocks, are variously infilled with argentiferous galena, chalcopyrite, iron-pyrites, quartz and metallic oxides. The richness in silver of some of them is remarkable. This district, too, will bear a considerable amount of prospecting.

The account given of the Tambillo and Igor deposits is not very encouraging; and those of Salpo and Milluachaqui, although of considerable importance, are from the industrial point of view, in a state of suspended animation.

With the exception of the coal-seams of Callacuyan, some 31 miles east of the city of Otuzco, all the coal-deposits of the province are concentrated in its northern portion. In thickness the seams vary between 6½ and 26 feet. and they occur invariably amid the sandstones, with a roof and floor of carbonaceous black shale. They are believed to be of Jurassic age. The coal of Huayday, on the extreme north-eastern border of the province, crops out about 6,500 feet above sea-level, towards the left bank of the rio de Chicama. It is of a brilliant black, very hard and heavy, compact, does not blacken the fingers, and in a chimney with a good draught, burns easily, yielding a great deal of heat. Its calorific power is estimated at 7,015 calories. Analysis gives the following results:—Hygroscopic water, 5·66 per cent.; volatile matter, 4·74 per cent.; fixed carbon, 79·74 per cent.;

and ash, 9·86 per cent. The Shalcoal, Pinchaday, Huaranchal and Canibamba coals are also described by the author, although from the tabulated analyses, it may be gathered that they are not quite of such good quality. But the Lagunas seam, about 20 feet thick, near the north-western border of the province, and only 6 miles distant from the Pampas railway-station, yields a greyish-black anthracitic coal of the following composition:—Fixed carbon, 82 per cent.; volatile matter, 9·5 per cent.; and ash, 8·5 per cent. Its heating power is equivalent to 7,039 calories, and, although it ignites with some difficulty, it burns well without crepitating.

In regard to mining operations generally in the province of Otuzco, the author criticizes adversely the want of method, foresight, and economy with which they are (with extremely rare exceptions) carried on. He describes at some length the metallurgical treatment of the ores, including amalgamation and lixiviation, and concludes with a prophecy of the brilliant future which awaits the mineral-industry of the province, whenever mining operations shall be methodically conducted, under skilled management, backed by ample capital. L. L. B.

MINERAL RESOURCES OF THE PROVINCE OF PATAZ, PERU.

Recursos é Importancia de la Provincia de Pataz. By FELIPE DE LUCIO. *Boletín del Cuerpo de Ingenieros de Minas del Perú,* 1905, *No.* 21, 60 *pages and* 8 *plates.*

After a geographical description of this mountainous province, part of which lies within the watershed of the great rio Marañón, the author proceeds to consider the question of ways of communication. On the very first page of his memoir he warns the reader that "no progress, moral or material" has been achieved in this region since it was first described by Don Cosmo Bueno in the year 1771; and the roads, bad or non-existent in so many provinces of Peru, are in perhaps a sorrier plight in remote Pataz than elsewhere. All the tracks at present in use pass over very steep gradients, and the only one that it would be possible to convert into a good road for wheeled traffic meets the line of the projected Marañón railway: the province of Pataz would then be placed within five days' journey of the Pacific coast. The entire mountain-massif which forms the right bank of the Marañón hereabouts is built of Upper Cretaceous limestones, which reappear on the left bank.

Where erosion has carved deep ravines within them, the underlying gneisses and schists are exposed. On the north, the limestones extend halfway up the great wall of the Andes, the core of which here seems to consist of a pseudostratified quartz-porphyry, amid which are seen great intrusive masses of hornblende-andesite. The argentiferous ores of San Lorenzo and Chontacocha occur in the last-named rock, while the schists and the porphyry are the matrix of the gold-bearing minerals. These latter contain a higher percentage of silver, in proportion as they occur nearer an andesite-intrusion. The southern area is covered by a boulder-clay and glacial conglomerate, here called *colorada,* while a more recent period of glaciation has given rise to the placers of the Rio Cajas.

Of all the gold-producing districts in the province, the most celebrated is that of Parcoy and La Soledad, where the deposits have been worked from time immemorial. The auriferous veins, striking parallel with the joints of the porphyry, have rather the aspect of bedded deposits, but may perhaps be more correctly described as lenticles. A description is given of the

El Gigante mine, where the mineral consists of auriferous arsenical pyrites more or less abundantly dispersed through barren quartz. Including this mine, it is estimated that the amount of gold still to be got in the Parcoy district from the deposits which have been prospected is 209,811 ounces. This leaves out of account several mines which have not been recently investigated, and there are, too, abundant occurrences where the gold-tenour is high but the extraction unprofitable; unless sufficient capital be embarked in the venture to permit of working on a large scale, and unless good roads be made. At El Gigante the amount of oxidized mineral is very small; generally, refractory sulphides predominate, and, by means of the cyanide-treatment a little over 40 per cent. of the gold can be extracted. Labour is cheap, although of poor quality; fuel is scarce, but the rio Llacuabamba would furnish sufficient motive power; provisions are cheap and good; and, as before mentioned, the means of communication are difficult.

In the neighbourhood of the town of Pataz, on one of the spurs which come down from the Eastern Cordillera, there are five or six distinct metalliferous " beds " of great thickness and extent, occurring, some in the blue slate which here overlies the porphyry, some in the porphyry itself, and some in a black crystalline rock which is intrusive within the last-named. Although mined in former times, these deposits are by no means worked out, and the author estimates the amount of ore still in sight as superior to that of the Parcoy district. The local conditions are, on the whole, favourable (roads always excepted), but the necessary labour would have to be imported. A passing reference is then made to the San Lorenzo mine, but the author refrains, for reasons which are duly set forth, from recommending the resumption of mining-operations there. Nor can he say much in regard to the Zarumilla mining-district, beyond advising those who may take up the Pataz workings to prospect in Zarumilla also.

A lengthy description is given of the placer-deposits of the rio Cajas, which appear likely to give rise to a prosperous mineral-industry.

An appendix is devoted to the semi-anthracite-deposits of Ancos in the province of Pallasca. These occur among slates, quartzites and limestones, in an area which has evidently undergone metamorphism; and the metamorphism is not alone regional, for an igneous dyke traverses the sedimentary rocks on the north-eastern flank of the Cerro de Cocabal, and to its influence the author attributes the anthracitization of the Ancos coal. The mineral is hard, makes very little small, burns with difficulty, does not cake or crepitate, and yields about 14·2 per cent. of ash. The fixed carbon amounts to 72·3 per cent., volatile matter to 8·2 per cent.; and hygroscopic water to 5·3 per cent. Experimental use of 20 tons of it on railway-locomotives with appropriate boiler-furnaces has given satisfactory results. The amount of workable coal in sight is estimated to average at least 4,000,000 tons, and this in one limb of the anticline alone: it appears probable that as much again will be found in the other limb of the anticline. The seams are separated in all cases from the schistose slates among which they occur by thin bands of a compact clay, varying in colour from white to bluish and reddish-grey and black.

The conditions for working are extremely favourable, ventilation being natural and easy, the evolution of marsh-gas being here out of the question; the coal can be got by adits driven (? one above the other) at appropriate intervals in the sides of the ravine of Ancos. As usual in Peru, the great difficulty is that of transport. L. L. B.

AURIFEROUS DEPOSITS OF SANDIA, PERU.

Informe sobre los Yacimientos auríferos de Sandia. By LUIS PFLÜCKER. *Boletin del Cuerpo de Ingenieros de Minas del Perú,* 1905, *No.* 26, *pages* 1-40, *and* 6 *plates.*

The placer-mining industry in the province of Sandia, flourishing in bygone ages, seems destined to re-emerge shortly from the depression in which it has long been plunged. This depression has been chiefly due to the lack of cheap labour, in sufficient abundance to work the deposits profitably by the primitive methods hitherto in vogue. The introduction of modern processes will eliminate this economic factor ere long, and thereby possibly inaugurate the hoped-for renascence of the industry.

The province is divided into two unequal portions, the smaller being the southern one, by the snow-capped Cordillera which encircles the Titicaca plateau. From the high summits which reach an altitude of 15,000 feet, there is a steep descent to the provincial capital of Sandia (7,000 feet above sea-level), and thence a more gradual slope northward. The southern portion forms a great pastoral district; while the northern, seamed by the narrow ravines which the mountain-torrents have carved deep in the slates, is given up (according to altitude) to the cultivation of maize, coca, coffee and indiarubber. Of the 20,000 inhabitants of the province, all but 800 are illiterate: from among them ordinary *peones* (" boys ") are recruited for the alluvial workings, but the better class of labour has to be looked for in other provinces. From the seaport of Mollendo, the traveller who wishes to reach Sandia, may use the Southern railway to take him 293 miles on his way as far as Juliaca, whence it is five days' journey by either of two roads up to Sandia. Apart from these, the ways of communication in the province are described as mostly execrable, some of them being mere self-worn tracks dating from before the advent of the white man.

A transverse section of the above-mentioned Cordillera, from south to north, shows sandstones, quartzites, glacial deposits, slates (forming the highest peaks), then the central core of granitic rock, followed in reverse order by slates, quartzites and sandstones. The bedding of the two last-mentioned rocks is generally vertical, while the dip of the slates (which constitute four-fifths of the eastern Cordillera, and are supposed to be of Silurian age) is extremely variable. The drift-deposits extend over almost the whole of the southern portion of the province, in the shape of loosely cemented conglomerates, the chief elements of which are quartz, sandstone, slate and ironstone. Upon them rest in many places erratic boulders of huge size. Nearly everywhere the presence of gold has been proved in these deposits, but the tenour in gold bears no relation to its proximity to the bed-rock, thus showing that concentration by water-action is here out of the question as an originating factor. That the deposits are largely of glacial origin admits of little doubt, although no striae have been as yet observed in the few places where the underlying rock is exposed. At the Ananea glacier, where a frontal moraine is actually in course of formation, the moraine itself is now worked as a gold-placer.

Three varieties of auriferous deposits are recognizable in the province of Sandia: (1) the gold-quartz-reefs; (2) the glacial and fluviatile drifts, and (3) the alluvia deposited by the existing rivers. The first-named must, in former days, have been the object of active mining-operations, but hardly any of them have been worked for a long time, and the author declines to predicate anything as to their present extent or value. To the Glacial

Drifts proper belong the enormous placer-deposits of Poto, which are certain to yield a considerable output of gold whenever they are worked on a large scale. The Aporoma placers are assigned to the older fluviatile drifts, and they also admit of working on a large scale. The small and sparsely distributed placers, built up from the alluvia of the existing rivers do not, on the other hand, admit of working on a large scale. In a small way, however, they are worked at a profit, and their accumulated output bulks considerably in the total gold-production of the province. These alluvial placers are called *aventaderos*, and the gold is nearly always concentrated at the bottom, above the slates or a stratum of clay. Nearly all the water-courses in the province carry gold, and the two great rivers, the Inambari and the Tambopata, considering their ample breadth and comparatively tranquil flow (the velocity of the current does not, as a rule, exceed 3 miles an hour), would form appropriate sites for gold-dredging operations. Electricity for power-purposes could be generated from the numerous tributary torrents.

In the fifth chapter of the memoir a detailed description is given of the glacial placer-deposits south of the Cordillera, including those of the mining-district of Poto. The entire area is situated at an altitude exceeding 15,000 feet above sea-level, and consequently the climate is what the Peruvians term "cold," but the country affords abundant pasturage for sheep and goats. Hydraulicking plant is or has been at work at San Antonio de Poto and Ajollani. The rich placers of Laca and Huancantira, at present worked by the Cuyucuyu Indians, would repay working on a large scale. Works for the treatment of the gold derived from the quartz-reefs of the district, few of which are at present mined, have been lately established at the foot of the Ananea range, near the lakelet of Rinconada. In this way reef-mining will probably revive in this area, as hitherto the miner has been obliged to leave untouched the low-grade ores, abandoning the workings so soon as the high-grade ores have been exhausted. The sixth chapter is devoted to the Aporoma placers (the total volume of auriferous gravel, etc., in these being estimated at 1,595,500 cubic yards), and to the gold-washeries along the rio Pulipuli (Infiernillo), and the rio Azunta. Then a short description is given of the mining-districts of Cotani, Monte Bello, and the rio Chailluma.

The ninth and last chapter embodies a synopsis of the present condition of the mineral industry throughout the province. The government records of the year 1904 show that 115 mining concessions had then been granted, but in the vast majority of cases no prospecting-work even had been done on them. The total output of gold from the province of Sandia for that year amounted to 3,826 ounces Troy, whereof 1,350 ounces came from San Antonio de Poto, 483 ounces were got from the quartz-reefs, and 1,993 ounces represent the yield of the labour of some 520 Indians working various drift- and alluvial-placers on their own account. The Cotani district contributed nothing to these totals. The causes which have so far checked the successful development of the industry in the province are (1) the general inaccessibility of the deposits, since with the exception of Poto, the roads (as aforesaid) are execrable; (2) the absence of such detailed investigation as would form a basis for fresh prospecting-work; and (3) the lack of local capital. To these may be added the general backwardness of the province, and the scant encouragement given to enterprizing prospectors or other investigators. There being no proper cadastral plan of landed properties,

the question of boundaries remains delightfully vague and confused. When these difficulties have been overcome, the mineral resources of the province will justify it in looking forward to a brilliant future. L. L. B.

GOLD-PLACERS AND LIGNITES OF TIERRA DEL FUEGO, SOUTH AMERICA.

Lavaderos de Oro de Tierra del Fuego. By JERMAN BRAIN. *Boletín de la Sociedad Nacional de Minería*, 1905, *series* 3, *vol. xvii.*, *pages* 69-74.

Rather more than half (10,800 out of 18,500 square miles) of the great island of Tierra del Fuego lies within Chilian territory. The numerous gold-placers which occur there have been worked for some time; but the full extent of their importance appears to have been appreciated only within the last three years, and it is now proposed to introduce into the country the system of steam-dredging which will enable mining-operations to be conducted on a much larger scale than hitherto.

A short historical summary is given, beginning with the year 1880, when an officer of the Chilian Navy published a description of the auriferous deposits. This is followed by details of the primitive fashion in which the alluvia have been worked, in localities where water is easily accessible: much precious metal is washed away in the tailings, and accurate statistics of the output are not forthcoming. Now and then, big nuggets have been found, and a list of these is given. One obtained in 1900, weighed no less than 590 grammes or 18·88 ounces Troy.

The geological structure of the country is not very complicated: along the western coast runs a prolongation of the Andes, of which the basement-rocks are schists and granites. East of this stretches a vast succession of clays, sandstones and conglomerates of Tertiary age, with a general north-easterly dip. These sedimentary deposits, although sufficiently compact and tough, are easily disintegrated by atmospheric agencies.

In the earlier (Miocene) portion of the succession occur several seams of lignite of fairly constant thickness, measuring each from 3 to 5 feet. They have been proved at several localities at some distance apart, and their composition appears to be as constant as their thickness. The following analysis of a specimen of lignite of Rio Oscar may be regarded as representative of the average: hygroscopic water, 25·85 per cent.; volatile matter, 34·35 per cent.; fixed carbon, 36·75 per cent.; and ash, 3·05 per cent. The heating power is equivalent to 3,868 calories. When exposed to the free air, the mineral crumbles with rather disconcerting facility, on account of the rapidity with which its large percentage of contained water evaporates. It needs to be dried slowly in stacks protected from the wind.

The author assigns reasons for believing that, at one time, all the above-described formations were mantled over by a poorly-auriferous gravel, whence the placers have derived the gold which is now accumulated in them. He then expatiates on the future industrial importance of the extensive peat-deposits, 8 to 10 feet thick, which lie along the valleys of a great many rivers. In these same rivers gold is found apparently everywhere, coarse in the upper reaches, finely divided in the lower. It is associated with ironsands, mainly consisting of magnetite and hæmatites. Occasionally, fragments of platinum and garnets are discovered among these.

The veins from which the gold was originally derived, would seem to

have existed at a great distance from the present deposits, judging by the rounded and polished character of the fragments of altered sedimentary rocks constituting the gravel and by the fact that none of the rocks represented are to be found in the neighbouring mountains.

The gold, accompanied by oxides of iron and occasionally pyrites, assays from 850 to 920 fine and is generally in the form of laminated particles of varying sizes, which only amalgamate with difficulty, owing, probably, to a coating of iron oxide, which prevents intimate contact with the mercury. Platinum has been found in small quantities.

H. D. and L. L. B.

KLEINITE, A QUICKSILVER-MINERAL FROM TEXAS.

Der Kleinit, ein hexagonales Quecksilberoxychlorid von Terlingua in Texas. By A. SACHS. *Sitzungsberichte der königlich preussischen Akademie der Wissenschaften*, 1905, *No.* 52, *pages* 1091-1094.

At the mineralogical Institute of the University of Breslau a specimen of a mineral designated as "terlinguaite" was lately received, which, on careful investigation, proved to be another and hitherto undescribed mineral. In the papers published in 1904, by Dr. A. J. Moses, terlinguaite was described as a monoclinic mercury oxychloride, corresponding to the chemical formula Hg_2ClO. Now, the mineral examined by Dr. Sachs undoubtedly crystallizes in the hexagonal system; it contains about 87 per cent. of mercury, from 7 to 8 per cent. of chlorine, and about 5½ per cent. of oxygen, a composition almost exactly expressed by the formula $Hg_4Cl_2O_3$ (or $HgCl_2 + 3HgO$). It occurs in small crystals, 1 to 2 millimetres only in length, in a highly argillaceous gangue, often raddled by iron oxides. It is soluble in moderately concentrated hydrochloric acid, and in nitric acid. In the purest variety, the crystals are sulphur-yellow, which gives place to an orange tinge where the gangue shows signs of decomposition. The lustre is comparable with that of the diamond, the cleavage is good, hardness, 3 to 4; and the specific gravity, 7·441 (less than that of either eglestonite or terlinguaite). The locality where it has been found is Terlingua, in the state of Texas. The proposed name kleinite is given in honour of Dr. Carl Klein.

L. L. B.

AURIFEROUS AND CUPRIFEROUS DEPOSITS OF GLOBE, ARIZONA.

Das Kupfer-Gold-Lager von Globe, Arizona. By W. GRAICHEN. *Zeitschrift für praktische Geologie*, 1905, *vol. xiii., pages* 39-40, *with* 1 *figure in the text.*

Some 10 miles west of Globe in Gila county, Arizona, almost precisely at the boundary of Pinal county, the Queen creek issues from the mountains, through a gorge cut in limestone at a point defined by a fault-fissure. In the steep walls of the gorge, a gold- and copper-ore deposit is exposed; several adits were driven in the hillside in 1903, and still more recently a shaft has been put down due north of the creek.

The deposit strikes nearly due north and south, and dips 32 degrees eastward. A band of dark quartzite about 70 feet thick courses through the limestone, and from 70 to 90 feet above this comes the ore-body, both that and the quartzite being traversed by numerous faults which all but cut

the strike of the rocks at right angles. Both the quartzite and the ore-outcrop may be traced for several miles, the former uninterruptedly and of generally uniform thickness, the latter in its northern and southern parts only at intervals and then of extremely variable extent; the thickness of the ore-deposits, too, which in the middle portion of the belt averages from 6 to 7 feet, northward and southward varies between a few inches and 9 feet.

At the outcrop, the deposit consists of a bedded ferruginous quartz, containing a small proportion of gold, but little copper. Sometimes the whole mass of the deposit is made up of carbonate of the latter metal. On the whole, the ores of copper predominate near the hanging-wall, while the ferruginous quartz is more restricted to the foot-wall, and there it is much richer in gold. Narrow veins a few inches thick, presumably of secondary formation and infilling, yield very high assays. Between the hanging-wall and the country-rock there is generally a geodic space of varying breadth, the walls of which are encrusted with gypsum.

The prospects of a great yield of both gold and copper are favourable. The author regards the deposit as being of sedimentary (bedded) origin, but points out that waters percolating from above probably dissolved away the limestone in places, forming hollows which were subsequently in part infilled with carbonates of copper. L. L. B.

TITANIFEROUS IRON-ORES OF THE LARAMIE RANGE, WYOMING.

Die Lagerstätten titanhaltigen Eisenerzes im Laramie Range, Wyoming, Ver. Staaten. By J. F. Kemp. *Zeitschrift für praktische Geologie*, 1905, *vol. xiii., pages* 71-80, *with* 7 *figures in the text.*

The author visited the deposits here described in the month of July, 1902, his interest in them having been aroused by their reputed similarity to the titaniferous magnetites of the Adirondacks. The results of his investigations regarding these latter were published in 1899, in the Nineteenth Annual Report of the United States Geological Survey.

The Wyoming deposits are located in the south-eastern portion of that state, in a section of the Rockies known as the Laramie range; this forms a belt striking north and south for some 20 miles, and consisting mainly of much-weathered pre-Cambrian granites overlain by Carboniferous Limestones; these again are overlain by red Triassic rocks, which in turn are succeeded by the Jurassic and Cretaceous formations. Through the southern portion of the range the Union Pacific railway is cut, reaching its summit-level at Sherman, 8,271 feet above the sea.

The existence of extensive magnetic iron-ore deposits in the hills north-east of the now populous town of Laramie was announced as long ago as 1849-1850; but their enormous extent was only fully realized by Dr. Hayden in 1868, and they were described as interbedded among the red felspathic granites, with the folding and fissuring of which they coincided. Thousands of tons of a boulder-gravel made up of the ore lay strewn about in Chugwater creek. These wonderful deposits were redescribed by Mr. Arnold Hague in the Reports of the Survey of the Fortieth Parallel in 1877, but it was reserved for the present author to prove by microscopic as well as macroscopic investigation that the actual country-rock of the ore is anorthosite, a rock closely allied to the labradorite-rock of the Adirondacks, of Canada, and of Norway. The anorthosite (and the ore-body itself) is traversed by

granite-dykes, frequently of granophyric character; these are more refractory to weathering influences than the anorthosite which they traverse, and stand out for distances of many hundreds of feet like low walls (3 feet or so in height). The titaniferous magnetite crops out near Shanton ranch in lustrous black wall-like masses, the biggest of which is about ¼ mile long, and averages 20 feet in breadth. It contains about 50 per cent. of titanic oxide and 34·3 per cent. of metallic iron. The surfaces of both the ore and the neighbouring rock have been rounded, smoothed and polished by wind-erosion. Occasionally a crust of rusty-brown limonite is found coating the fissures, but, on the whole, the ore is quite black and fresh-looking. In microscope-slides the magnetite is seen to contain numerous inclusions of green spinel, an association which vividly recalls the magnetite-spinellite of Rutivaara and the mineral of the Peakskill mines, in the Hudson river-valley (New York). The most considerable outcrops of ore are found in a ridge through which the Chugwater creek cuts its way, 6¼ miles north of Shanton ranch. This ridge is known as Iron Mountain, and trends north-westward, the major portion being on the north side of the creek. The ore rises like a black wall out of the anorthosite, and is traced over a distance of at least 2 miles: it contains from 51 to 53 per cent. of metallic iron, and rather more than 23 per cent. of titanic oxide. The main mass is at a level of 1,000 to 1,300 feet above the neighbouring valleys, but two secondary dykes of ore may be traced half way down the hill. On the south side of the Chugwater-creek ravine, there is an outcrop some 16 feet broad, exhibiting an intimate intermixture of titaniferous iron-ore and olivine; at all other points the ore is absolutely free from admixture with foreign minerals.

The author discusses the mineralogical and chemical evidence, with the view of showing that all these ore-bodies are true eruptive dykes, the unmistakable result of separate intrusion, and they differ in that respect from the deposits studied in the Adirondacks. L. L. B.

PHOSPHATE-DEPOSIT AT MARTINIQUE, WEST INDIES.

Sur un Gisement de Redondite à la Martinique. By A. Lacroix. [*Bulletin de la Société française de Minéralogie*, 1905, *vol. xxviii.*, *pages* 13-16.

Many of the smaller islands dotted about in the Pacific ocean and the Caribbean sea contain guano-deposits, which have undergone considerable changes under the influence of such agencies as saturation by tropical rains or by sea-water, both of these causes sometimes acting simultaneously. The soluble salts thus leached out of the guano are in some instances lost entirely, but in others they are absorbed by the soil of the island; and, if this be of coral-reef origin, more or less compact masses of a tricalcic phosphate are the result. Such is the case in the island of Redonda in the Lesser Antilles, whence the mineral-name redondite has been derived. At Clipperton Atoll, in the Northern Pacific, a similar phosphatic deposit has been formed by the progressive alteration of a trachyte—due to the chemical action of ammonium phosphate on silicates of alumina.

In the course of his journey to Martinique, to investigate the conditions of vulcanicity there on behalf of the French Government, the author discovered on the islet of La Perle, off the north-western coast, a little way north of the now abandoned village of Prêcheur, a phosphate-deposit of

this kind. This barren islet, like the neighbouring coast, is built up of an andesitic conglomerate, which here is covered by a crust, several inches thick at the very least, of a banded, brown, compact mineral, that proves to be a pure hydrated phosphate of alumina. The immediately underlying andesite is completely decomposed. It seems probable that similar deposits occur on the Diamond islet, south of Martinique; on the Sugarloaf islet, off the north-eastern coast, and on other rocks along that coast which form the resting-place of countless myriads of sea-birds.

A comparison of chemical and mineralogical results shows that the soluble phosphates derived from guano have the same effect on silicate-rocks of the most various composition. It does not seem to matter whether these be trachytes or andesites, diabases or gneisses. The author is not at present prepared to make any statement as to the possible industrial importance of the La Perle deposit. L. L. B.

MINERALS OF WESTERN BORNEO.

Geologie eines Theiles von West-Borneo, nebst einer kritischen Uebersicht des dortigen Erzvorkommens. *By* N. Wing Easton. *Jaarboek van het Mijnwezen in Nederlandsch Oost-Indië,* 1904, *vol. xxxiii., Wetenschappelijk Gedulte, pages* 509-524.

The memoir on the geology of Western Borneo occupies an entire volume of the *Jaarboek*, and is accompanied by an atlas of maps and sections and another containing twenty-one plates of microphotographs. In this abstract, however, reference is made only to the 41st section of the memoir, which deals with the useful minerals.

This portion of Borneo is not precisely conspicuous for its mineral wealth owing to the geological structure of the country: no great fault-fissures are there to encourage the formation of deep-seated metalliferous veins, and such fissures as are infilled with quartz always pinch out at a comparatively shallow depth. In Carboniferous times, the area lay deep below the sea, where no coal-seams could form; in Tertiary times it had already become dry land, hence, for an opposite reason, no later coal-deposits of any industrial importance were formed. Moreover, it is urged that the comparative scantiness of animal life throughout geological time in this area, all but precluded the possibility of the formation of petroleum-deposits.

Twenty localities are enumerated where the Chinese used to wash alluvia for gold, but there are many other localities where gold was and still is got. The only placer-workings of any great importance, however, now in activity are at Selinse, near Bengkayang. The question of the original matrix of the precious metal is discussed in some detail, and the author shows how irresistible is the evidence which has led him to conclude that the gold is derived from the super-silicated members of the quartz-porphyry group; it is not, as he and other observers long thought, connected with the granites, diorites and diabases of the area. It is probable that the proportion of gold present in the actual outcrops of quartz-porphyry and sandstone-conglomerate would not repay the cost of mining, crushing, etc., unless operations were conducted on a very large scale indeed.

Diamonds have been obtained in three localities—only one of which (the middle course of the Landak river) lies within the district surveyed by

the author. Here the precious stones have been got from the river-bed, and from the alluvial deposits by which it is fringed: these are quartzite-gravels not exceeding 8¼ feet in thickness, which lie immediately upon Triassic and Cretaceous rocks. There is a good deal of pyrites in these diamond-bearing gravels, and black mica and gold also are invariably present. The so-called *lebur*, small, very hard, blue, grey, brown and black rounded pebbles, are said by the Malays to be infallible indicators of the presence of diamonds. Many of these pebbles are undoubtedly of corundum, and others are probably of jasper and other varieties of silica.

The Landak diamonds have very often a fine crystalline form, and are flawlessly water-clear; but there are also many pale-yellow stones. Most weigh less than a third of a carat, and stones heavier than 2 carats are exceptional. It is thought, however, that bigger diamonds were got here in former days: the output has diminished greatly within the last twenty years.

The author believes that the diamonds date from an older period than the gold. He suggests that the dioritic and noritic rocks which solidified from their molten condition in Triassic times, gave rise to corundum as a contact-mineral (as at Klausen in the Tyrol), and that the diamonds originated in connection with the olivine-bearing rocks.

Cinnabar, with which gold is invariably associated, has been found in half-a-dozen localities, in the neighbourhood of quartz-porphyry outcrops. From these rocks, too, are doubtless derived the sulphidic ores of copper, lead and iron reported as occurring in various districts. The mention of molybdenite and bismuth-ore occurrences closes a somewhat unsatisfactory catalogue: unsatisfactory, that is, from the miner's point of view, as, of all the useful minerals found in Western Borneo, gold alone occurs in quantity sufficient to make it of industrial value. To the quartz-porphyries may be traced directly or indirectly the genesis of all these minerals, with the above-mentioned exception of the diamonds. L. L. B.

POSIDONIA BECHERI IN PRODUCTIVE COAL-MEASURES.

Ueber das Hinaufgehen von Posidonia Becheri in das produktive Karbon. By FRITZ FRECH. *Centralblatt für Mineralogie, Geologie und Paläontologie*, 1905, *pages* 193-195.

The author points out that hitherto all writers seem to have agreed in regarding this lamellibranch as one of the most characteristic fossils of the upper portion of the Lower Coal-measures; but in 1899, Dr. Holzapfel mentioned the significant fact that he had collected *Posidonia Becheri* in the Coal-measure shales which overlie the lowest coal-seam of the Inde basin (the Wilhelmine seam) in the Probstey Wood, near the railway station of Stolberg, Aix-la-Chapelle. The Breslau museum has lately acquired new material, which removes all doubt as to the upward range of this *Posidonia* into the Lower Coal-measures at any rate. One such specimen from the Lower Coal-measure clay-slate of Alnwick corresponds precisely with Prof. Frech's own figures of German examples. Other specimens obtained in great abundance from Upper Silesian collieries and from the Lower Coal-measures of Mons are slightly different, and are described by the author as mutations from the typical *Posidonia Becheri*, as defined by Dr. Bronn. The mutation is distinguished by its finer costation from the type; but

both the fine-ribbed and the coarse-ribbed shells are found together in the same hand-specimen, as at Bordeira in Portugal and Lough Shinny in Ireland. The inevitable conclusion is that *Posidonia Becheri* undoubtedly ranges high up in the Coal-measures, in these islands as well as on the Continent, and can no longer be regarded as especially characteristic of the Lower Coal-measures. L. L. B.

MAGNETIC PHENOMENA IN BAUXITES, ETC.

Magnetische Erscheinungen an Gesteinen des Vogelsberges, insbesondere an Bauxiten. By — Köbrich. *Zeitschrift für praktische Geologie*, 1905, *vol. xiii., pages* 23-36, *with* 1 *figure in the text.*

A chance observation led the author to establish the fact that the bauxites, etc., of the Vogelsberg are undoubtedly possessed of magnetic properties; and he regarded the pursuit of the investigation as of practical importance from the point of view of the mining industry of Upper Hesse. One consideration, of course, was that the knowledge that sundry basalts and associated rocks were capable of influencing the compass-needle would impose caution on those entrusted with surveys, etc., in and about the mines (in the course of which the compass would be utilized), and would help to account for certain erroneous results. Another consideration was that the demonstration of a given degree of magnetism, in certain rocks which sometimes occur in association with the practically non-magnetic brown hæmatite, might possibly lead to the elaboration of a magnetic separation-process for industrial purposes. For instance, it is not improbable that it may be found practicable to separate magnetically the bauxites rich in iron from those that are comparatively free from it. More speculative still, perhaps, is the hope that the bauxite and the basalt may be eliminated from the brown hæmatite on the same principle.

The bauxites of the Vogelsberg are undoubtedly of basaltic origin, and may be defined as lateritic decomposition-products of the surface-rocks—a decomposition which may have been due either to tropical climatic conditions in former ages, or to "post-volcanic exhalations," most probably the latter. In view of the genetic connection of the bauxites with the basalts, the author extended his investigation to these, and to the "basaltic brown hæmatites" of the district. He tabulates the results of magnetic tests applied to 212 rock-specimens, and points out that the so-called "black basalts," or "older flow-basalts" of Dr. A. Streng, probably owe their magnetic properties to the presence of magnetite among their constitutents: this applies also to certain nephelinites, dolerites, and gabbros. The so-called "blue and grey basalts" show little magnetism when fresh, but far more when decomposed. As decomposition progresses, however, the magnetic properties vanish, instead of increasing proportionately. As to the brown hæmatite, the purer it is, the freer from basalt-residue, the less does it show of magnetism. The bauxites, especially those that possess a deep-red coloration, are characterized by magnetic properties. To which constituent these properties were due, was a problem which the author set himself to solve, and he found that the seat of the magnetism lay in certain red grains, which were tiny crystals of olivine (derived from the basalts) enveloped in a crust of iron-oxide of varying thickness, the crystals being in part quite fresh and in part completely altered into iron-oxide. He observed this alteration in all its stages. L. L. B.

IRON-ORES AT NEUMARKT IN UPPER STYRIA.

Das Eisenstein-Vorkommen bei Neumarkt in Obersteiermark. By J. HÖRHAGER. *Österreichische Zeitschrift für Berg- und Hüttenwesen*, **1903**, *vol. li., pages* **337-339** *and* **352-355.**

The deposits of iron-ore at Pöllau, about 4 miles from Neumarkt, are of considerable extent. The ores contain from 60 to 64 per cent. of iron and 0·16 per cent. of titanium; they resemble Swedish ore, and the magnetic ironstone and hæmatite are always intimately mixed. Their richness, and the small but valuable proportion of titanium make these ores suitable for enriching the charge in a blast-furnace.

The mines were bought, in 1460, by the Convent of St. Lambrecht, and worked by them until about 1850. The ore was reached by a vertical shaft about 500 to 600 feet deep, and the workings extended horizontally for about 2,200 feet. Although the mines have been worked for nearly 500 years, they cannot be exhausted, and plenty of good ore may exist in the abandoned workings, as well as in the parts still intact.

As the demand for iron-ore is greater than the supply, it appears probable therefore that many abandoned mines, among them those at Neumarkt, might with advantage be re-opened. E. M. D.

HALLSTATT SALT-WORKS IN PREHISTORIC TIMES.

Der Hallstätter Salzberg in seiner Bearbeitung zur prähistorischen Zeit. By AUGUST AIGNER. *Österreichische Zeitschrift für Berg- und Hüttenwesen*, **1903**, *vol. li., pages* **399-402**, *and* **1** *plate.*

The remains indicating that salt was worked by prehistoric races, are of two kinds, above and below ground. The former and the most ancient, consist of fragments of pile-dwellings, with four clearly marked strata of civilization, wood, pottery, pieces of bronze and iron, burnt stones, wooden planks and water-gutters. The whole site, overgrown with a thick layer of peat, affords clear evidence that a brine-spring flowed in the neighbourhood, and that the workers collected the brine and evaporated it by the aid of red hot stones. Elsewhere in the district, in the neighbourhood of brine-springs, calcined heaps are found of little clay-bricks, kneaded by hand, and supposed to be directly connected with the ancient salt-works. The settlement at Hallstatt was probably abandoned 2,900 years ago. The inhabitants were content to extract salt from the brine, and did not quarry the rock, because polyhalite, an invariable accompaniment of rock-salt, has not been found here. The rude character of the remains and the thickness of the peat overlying them prove that they date from a very remote age.

The presumably Celtic race, which had left thousands of graves, containing weapons, utensils and ornaments, belonged to a later period, about 600 B.C. They penetrated into the salt-mountains, and traces of their workings abound to a depth of 590 feet. The miners certainly possessed some knowledge of ventilation, otherwise they could not have penetrated to so great a depth, by the aid of artificial light.

The "Celtic shaft" extended vertically at least 800 feet. The mine seems to have been worked dry, and only the richest rock-salt was mined. The progress of the shaft was evidently stopped by an inrush of water. The remains include a wedge-head of black serpentine, fragments of a bronze

drill, bone awls, broken pottery, wooden cups, horns, skins, furs, woven stuff, coloured leather, a leathern case or bag, etc.

After the working of the mine was stopped, a long period of inactivity supervened, until the appearance of the Romans in the district. It is supposed that they merely evaporated the brine, and of this there must have been a vast supply, because, the older workings having probably broken down the protecting roof, the water rushed in, and dissolved the salt, and an outflow of brine was the result.

The present system of salt-mining dates from 1308. E. M. D.

SALT-MINING AT ISCHL, STYRIA.

Über den Kaiser Franz Josef-Erbstollen in Ischl. By AUGUST AIGNER. *Mittheilungen des Naturwissenschaftlichen Vereines für Steiermark*, 1904, *vol. xli.*, *pages* 119-132, *and* 1 *plate.*

Although the salt-mining industry in this district dates as far back as 1563, it cannot compare in antiquity with that of other regions of the Eastern Alps. This comparative juvenility is, however, all to the advantage of the Ischl miners, as they have been enabled to profit by the accumulated experience of their perhaps less fortunate neighbours, and the progress of modern science has placed at their disposal more powerful weapons wherewith to overcome the hostile forces of nature than could be wielded by those who worked the older mines.

The salt-formation at Ischl, moreover, in contrast with the other Alpine deposits which tend to assume the shape of a dome or a cupola, may be likened to a reef, and consequently the serious accidents connected with the roof of those deposits are of unlikely occurrence here. Fault-fissures running down to depths of 1,000 feet or so in those other districts have also proved a great hindrance to the workings, while the rich Haselgebirg salt-mass of Ischl (opened up below the Leopold adit) has remained untouched until the recent advances in the science of mining should permit of its being worked without difficulty. Looked at as a whole, the Ischl "reef" is really an elongated lenticle, striking east and west, thinning out towards the surface and widening out in depth, while its pitch is almost perpendicular.

The Kaiser Franz Josef deep-level adit, visited by the author in September, 1904, has proved a considerable north-westerly extension of the rock-salt deposit towards Pfandl. It opens up a completely untouched mass of mineral, which has not yet been bottomed, although the depth of 1,128 feet has been reached, and containing 68 per cent. of pure salt. The deposits overlying the Leopold adit, which have been worked for well nigh three centuries and a half, will probably be exhausted at the present rate of output by the year 1918. It is calculated, on the other hand, that the mass opened up by the new deep-level adit will take several centuries to exhaust, even when an increasing output is reckoned with. The adit is to be completed in the year 1906; electricity is being used as the driving-power. Once mining begins, it is proposed to crush the rock-débris into a sort of sand, and, mixing it with a suitable quantity of water, to pour it through iron pipes, in the form of a liquid "packing," into the cavities which will be left by the extraction of the salt. L. L. B.

GOLD-MINING AT BRÁD, TRANSYLVANIA.

Der Goldbergbau der Rudaer Zwölf-Apostel-Gewerkschaft bei Brád in Siebenbürgen. By JULIUS BAUER. *Berg- und Hüttenmännisches Jahrbuch der k. k. montanistischen Hochschulen zu Leoben und Příbram*, 1905, *vol. liii., pages* 85-204, *with* 28 *figures in the text and* 4 *plates.*

In the neighbourhood of the headwaters of the White Körös, hidden away among the andesite-domes of the old county of Zaránd, lie the most considerable gold-mines and stamp-batteries to be found within the limits of the Austro-Hungarian Monarchy. They are the property of the "Twelve Apostles" (co-operative) syndicate of Ruda, and, in view of their large output and up-to-date installation, they are ahead of any other gold-mining enterprise in Europe.

The mines occupy an area which may be described as an elongated quadrangle, extending from east to west along the Kristyor-Ruda or Muncsel range in the Csetrás mountains. There appears to be no doubt that the deposits were worked as far back as the times of the Romans; and indeed palpable evidence of the fact is forthcoming to the present day, in the shape of old galleries and stairways, wooden wheels used in draining the workings, inscribed mortars, and other Roman relics. The mineral-industry in that region was apparently far more prosperous and active then than it is even now, but it is supposed that the Romans got the greater part of their gold from the placer-deposits and river-alluvia. No records survive as to what happened to the workings in the Middle Ages; in the eighteenth and early nineteenth centuries the mines were worked on a comparatively small scale, but they were laid waste during the civil war of 1848-1849, and it was only in 1884 that they passed into the possession of their present owners.

The rocks of the district consist of eruptive basalts (melaphyres) of Triassic age; reef-limestones (Klippenkalke) of Jurassic age; eruptive porphyrites, probably post-Triassic and certainly pre-Cretaceous; Carpathian sandstones, of Cretaceous age; sedimentary deposits belonging to the Mediterranean division of the Miocene; and eruptive andesites, also of Tertiary age. These are overlain, in places, by various drift and alluvial deposits. The andesites, orographically the predominant rocks of the neighbourhood, are also industrially of extreme importance, since it is with them that the gold-occurrences are intimately associated. Four varieties of andesite are recognized among them, and these, in the presumed chronological order of eruption, are: (1) pyroxene-hornblende-andesites; (2) hornblende-andesites; (3) dacites, or quartziferous biotite-hornblende-andesites; and (4) garnetiferous dacites. The auriferous veins, coursing through sometimes both the sedimentary rocks and the eruptives, occupy fissures which were probably originated by a contraction of the earth's crust, proceeding from north-east to south-west, at an epoch subsequent to the eruption of the andesite-volcanoes.

The difference of level between the Ruda valley and the main valley of the district, that of the White Körös, appears to represent the workable height of the gold-mines. Still, as exploration-work in the deep levels is by no means at an end, it would be premature to assert that the veins will not prove gold-bearing to a depth far greater than is at present admitted. Generally speaking, the increased amount of visible native gold is in this district a good indicator of enrichment of the reefs or veins; and, conversely, when the veins show an increased percentage of the precious metal, native gold in the free state may be looked for with some confidence. The occurrence of barren breccia-veins, locally known as *glauche* or *glam*, of earlier

formation than the metalliferous veins, appears to be characteristic of Transylvania.

The entire output of the various mines belonging to the "Twelve Apostles" syndicate converges on the Viktor deep-level adit, constituting the main haulage-way: this also drains off the water from two districts out of the three into which the mines are grouped. A detailed description is given of the methods of working, ventilation, haulage, etc., also of the great central stamp-batteries at Gurabárza. With regard to power, it is distributed from three electrical stations, electricity being used for every conceivable purpose connected with the mines, and for lighting the villages which have grown up round them. The output of gold is tabulated, from the beginning of 1885 to the end of 1904: that for the whole period was 450,244 ounces, and for the year 1904 alone 45,411 ounces. The yearly increase has been very marked and uninterrupted since 1899, and indeed the share of the Ruda (Brád) mines in the gold-output of the whole Austrian Empire is not far off one-third. There is a certain amount of leakage due to theft, despite the presence of a detachment of *gendarmerie* specially stationed at the mines.

With the modernization of the methods of working, the necessity for a more abundant fuel-supply than that furnished by the timber of the neighbouring forests made itself felt; and, luckily for all concerned in the prosperity of the mines, extensive brown-coal deposits have been proved near at hand. The seams occur in the Tertiary beds which overlie the Jurassic reef-limestones; the two thickest at present known measure respectively 3¼ and 10 to 13 feet. It is quite possible that further workable seams will be ultimately found at depths greater than the lower and thicker of these two. Experimental borings and geological surveying are still in progress. Meanwhile, a colliery is in active work at Czebe, on the thick seam, which has here a blackband parting from 6 to 12 inches thick. The output for 1904 amounted to 10,540 tons. Work in the Mesztákon colliery, on the 3¼ feet seam, was finally stopped in 1897. The brown coal is used without any preliminary hand-picking or preparation of any kind, and its heating power lies somewhere between 4,000 and 4,500 calories. The mineral from the thin seam is really of better quality than that from the thick. The author is very hopeful as to the future extension and industrial importance of the coal-field. He concludes with a lengthy argument in favour of a much more active development of gold-mining in the Austrian Empire, and points out incidentally that the cost of extraction at Ruda is only 40 per cent. of the average cost of extraction in the Transvaal. L. L. B.

THE OUTPUT OF PRECIOUS METALS IN RUSSIA.

Die Edelmetallgewinnung Russlands. *By* F. THIESS. *Zeitschrift für das Berg-, Hütten- und Salinen-wesen im preussischen Staate*, 1905, *vol. liii.*, *Abhandlungen*, *pages* 1-6.

Of the total output of gold in the Russian Empire more than 70 per cent. is produced by Siberia, mostly in the form of placer-gold. The latest statistics, which give the results for the year 1901, declare a total of 39,142·15 kilogrammes (1,258,420 ounces) for Siberia, the Urals and Finland combined, an increase of 359·93 kilogrammes (11,571·75 ounces) as compared with the

preceding year. Eastern Siberia produces, perhaps, ten times as much gold as Western Siberia, the Olékma-Vitimsk deposits being in all probability the richest in the whole of that stretch of Asia. These deposits fall within the mining district of Irkutsk, and their maximum output was reached in 1880, although rich finds are still reported from there. Despite the severe penalties enacted by Russian law, much of the gold got from the smaller mines in Siberia is smuggled across the frontier into China, some authors estimating the amount thus smuggled as being equivalent to one-fifth of the total Siberian output. The farther east one goes in that part of Asia, the worse do the means of communication (in the matter of roads) become, and the higher are the wages that have to be paid to the miners.

The gold-mining districts of the Urals lie within the governments of Perm and Orenburg, a continual decrease in output from Perm having been recorded since 1899. The gold-output from Finland or Finnish Lapland is comparatively insignificant. The total number of workpeople employed in the gold-mining industry of Siberia, the Urals and Finland, during the year 1901 amounted to 86,720.

Platinum is got exclusively in the Urals, from mines which lie along the slopes of a range some 87 miles long, in the government of Perm. The deposits of the western slope (Nizhni Tagilsk) are said to be more productive than those of the eastern (Blagodat). In the year 1901, no less than 120 platinum-washings were at work, producing between them 6,371·81 kilogrammes (204,853·69 ounces) of raw metal. On the whole, it is considered that the platinum-output of Russia has increased, despite the temporary set-back in 1900, caused by the unfavourable conditions of the weather which hindered the working of the mines. Very little of the output (which is mostly exported to Great Britain and America) is refined locally. Such valuable associates as iridium, osmium, and palladium are practically always present in the unrefined ore.

Argentiferous lead-ores are got in the Altai, in the Nerchinsk district of Transbaikalia, in the Kirghiz steppes of the Semipalatinsk district, and in the district of Viborg in Finland. The output of silver from Siberia has continuously diminished since 1890, various causes for this diminution being assigned, such as the increasing poverty of the ore, the absence of fuel, the freedom of the peasants from bondage (corvée?), etc. Since the liberation of the serfs, wages in the Altai have gone up year by year, while the hours of labour have been shortened. The forests in the neighbourhood of the mines have been gradually cleared away, and fuel can only be brought from great distances, over bad roads, at a prohibitive cost. L. L. B.

PETROLEUM-INDUSTRY IN RUMANIA.

L'Exploitation du Pétrole en Roumanie. By — ARON. *Annales des Mines*, 1905, *series* 10, *vol. vii., pages* 380-464, *with* 6 *figures in the text and* 3 *plates.*

In the list of the world's petroleum-producers Rumania occupies the fifth place, below Galicia and above India. The annual output from that small kingdom has increased from 3,000 tons in 1860 to 410,000 tons in 1904, and the expansion is continuing at an accelerated pace. Yet exploration-work has been confined to a comparatively restricted area, the oil-industry being chiefly concentrated in the district of Prahova, which itself accounts for nine-tenths of the total output. Thus it is that but a small portion of

the petroliferous belt can be regarded as thoroughly known. Mr. Aron's memoir is largely based on the data accumulated in the course of a journey which he made to Rumania in 1903, in order to study the petroleum-question there in all its bearings.

Broadly speaking, Rumania is orographically divisible into three distinct regions, sensibly coincident with three geological divisions. These are, proceeding from south to north: (1) the plains, made up of Quaternary alluvia and Neogene sediments, extending from the Danube up to Bukharest; (2) the hill-country, or sub-Carpathian region, extending from the western province of Oltenia northward to the Bukovina, built up of Miocene and Pliocene sediments; and (3) the mountains, forming the natural frontier between Rumania and Hungary; these, throughout the Moldavian province, are built up of the Flysch, a system which includes deposits ranging in age from the Neocomian to the Oligocene. West of the Dambovitza, and locally in the extreme north of Moldavia, the mountains are formed of eruptive rocks and crystalline schists, amid which recur a few outliers of Mesozoic sediments (reef-rocks). All these rocks have been more or less affected by the Carpathian uplift. By this term, not one movement, but repeated movements are implied, which are supposed to have taken place in the interval between the deposition of the Sarmatic and that of the Pontian sediments (Meotic epoch, equivalent to a part of the Miocene).

The oil-bearing strata appear to be confined to the Flysch-belt in the mountains and to the sub-Carpathian region, as petroleum in workable quantities has not been struck in the plains or in the region of the reef-rocks (*klippen*). The petroliferous belt attains its maximum width of 25 miles or thereabouts in the Prahova district. The oil occurs in strata of different ages: thus, unworked petroleum-deposits of Cretaceous (Senonian) age are found in the districts of Prahova and the Dambovitza, while the Paleogene formation (Eocene and Oligocene) includes most of the oil-bearing horizons of Moldavia and a good many of those of Muntenia. These Paleogene belts are not generally of very great extent, but the oil is of good quality and the flow is constant. At Doftaneti it is richer in paraffin than elsewhere. The oil-belts in Muntenia range sensibly parallel with the mountains, but in Moldavia their strike makes more or less of an angle with the trend of the mountains. The Neogene oil-belts (for the most part Miocene) occur exclusively in the sub-Carpathian region, among strata which have suffered extreme disturbance. They are generally longer than the Paleogene belts, one of them measuring 22 to 25 miles from Baikoí to Gura-Oknitza. They are very clearly concentrated about the great bend of the Carpathians; and, on account of their greater proximity to the surface, they have been far more actively investigated than the older oil-belts. The flow of petroleum would seem to be somewhat irregular, but this may quite possibly arise from the technical conditions of working rather than from any deficiency in the natural supply.

The association of rock-salt with petroleum is magnificently exemplified in Rumania; the former generally occurring in the central portion of the anticlines, while the latter lies near at hand, but a little lower down. The presence of oil in the Neogene sediments is an almost invariable indicator of the existence of a mass of rock-salt along the same line of dislocation. It is true that the richest deposits of either one do not occur in immediate association (that is, in strata of the same age) with the richest deposits of the other, but this does not invalidate the undoubted general

relationship between the two. Petroleum, according to the favouring conditions of pressure and permeability, migrates easily from one stratum to another, and chronological considerations are in such a case peculiarly ineffectual arguments.

The author visited in greatest detail the region of Campina-Bustenari, which includes the most actively worked oil-belt in the whole of Rumania. This belt extends eastward for 8¾ miles from Gura Draganesi to Bustenari, and lies all but completely within Meotic beds (uppermost Sarmatic or lowermost Pontian). The Meotic here forms an anticline which is slightly bent over to the north, and is separated on that side by a fault from the barren Helvetian (otherwise known as saliferous Miocene). At one time, it was thought that the northern limb alone was oil-bearing, and most of the borings and shafts were put down on that side, not far from the summit of the anticline. Borings recently put down on the southern limb have shown equally good results, and the workable breadth of the belt may be estimated at 2,000 to 2,625 feet. The axis of the anticline dips slightly from east to west, with the result that, while the depths of the shafts around Bustenari rarely exceed 260 to 390 feet, round about Campina and Poiana the oil cannot be got from depths of less than 820 to 1,970 feet. The flow is by no means constant from one end to the other of the belt, and the duration of a given well varies considerably. Some have yielded oil for many years on end, while others were necessarily abandoned after a few months. In 1903, this belt alone accounted for 87 per cent. of the total petroleum-output of Rumania.

The crude oil is generally very dark in colour, olive-brown or blackish brown, and exhibits a characteristic greenish fluorescence. It emits usually a slight odour of ether, and, except in the case of the very dense varieties, boils between 77° and 140° Fahr. The Rumanian petroleum is comparable with that of Baku, rather than with the Pennsylvanian oil. The percentage of paraffin is extremely variable, ranging from *nil* at some localities to 5 or 6 in others. The crude oil contains practically no oxygen, and very small proportions of sulphur.

During three or four centuries the Rumanian peasants appear to have worked the oil-deposits in the most primitive fashion, and the start of the modern industry may be held to date from the Paris Exhibition of 1867, to which samples of the Pacuretzi petroleum were sent.

A description is given of the former system of working, by means of comparatively shallow diggings and quadrangular pits. Then, the shafts, which form the transition between these and the more modern methods of boring, are described. They rarely exceed 600 feet in depth, are of quadrangular form, usually lined with oaken or beechen logs, and are poorly lighted by means of reflectors. The ventilation is defective, and many of the workpeople perish from suffocation. Explosions and falls of rock, attended with disastrous results, are sufficiently frequent to have called for the intervention of the Government; but the workings are so disseminated as to make thorough administrative inspection difficult.

The first mechanical boring apparatus used in Rumania was set up in 1887 in the Campina district. The Canadian type of borer is almost invariably the pattern selected, and is likely to remain so, as the stratigraphical conditions in nearly all the districts here described preclude the use of the Pennsylvanian type of boring-tool. But, as the borings increase in depth, the slowness inherent in the Canadian system, suggests the necessity of

discarding it in favour of one of the various hydraulic systems (Raky, Vogt, Trauzl, Rapid, etc.). Statistics of cost of plant, labour, etc., are discussed in detail, together with the average annual output in the Campina-Bustenari belt, and it is shown that the prime cost of a ton of crude petroleum there is 14s.

The fourth, and perhaps the longest, chapter of Mr. Aron's memoir is devoted to a consideration of the outlets which can be secured for Rumanian petroleum when placed on the market. In 1903, the home-consumption amounted to something over 132,000 tons (of which 97,000 tons were residues), while the output of crude petroleum for that year was 384,000 tons. It is believed that this consumption could be enormously increased (in a country of 6,500,000 inhabitants) if greater facilities in the way of village-stores and more uniformly-refined oil were offered to the rural purchaser. Moreover, what with state and municipal taxes, and what with the plundering instincts of the middleman, the retail-price is prohibitive. In order to favour the small refineries the flash-point has been fixed at a dangerously low figure (73° Fahr.) for a country where the summer is very hot.

The residues, the calorific power of which is shown to be 30 or 40 per cent. greater than that of Cardiff coal, are by way of being used on a large scale for driving the locomotives of the Rumanian State railways: it was expected that, at the end of 1905, more than 92 per cent. of the engines would be using liquid fuel. Petroleum-residues are also being more and more used on board the vessels of Rumania's infant navy and merchant-marine, and for heating the boilers in various factories.

It is possible to paint with glowing colours, when we come to the exportation side of the picture. The statistics show an almost unbroken increase, especially marked of late years. Although Rumania plays still an insignificant part, in comparison with her gigantic rivals in the world's markets (the United States and Russia), her favourable geographical position in regard to the best European markets will prove an important factor in the near future. Curiously enough, the neighbouring Balkan States have allowed the petroleum from Baku to supplant the Rumanian article, but this is merely another symptom of the ridiculous racial hostility which paralyses the progress of South-Eastern Europe.

There is room for considerable improvement in the ways and means of communication. Pipe-lines have been laid down, but for comparatively short distances. Not only do the producers complain of the railway-rates, but the facilities for traffic are ludicrously inadequate (the line from the capital to the Black Sea is single-track).

The fifth and last chapter deals with the legislative and economic conditions of the industry. Laws quite recently promulgated, after investigation by specially appointed committees, are expected to obviate many difficulties. The defects in technical organization, we are told, are in process of amelioration; but a satisfactory commercial organization is still to seek. In regard to financial matters and the promotion of companies, etc., it is impossible to say anything here without libelling certain powerful trusts, but the reader will reap both instruction and amusement if he consults the original memoir.

L. L. B.

THE UZNACH BROWN-COAL WORKINGS, SWITZERLAND.

Bericht über die Exkursion nach dem Rickentunnel, nach Uznach und dem Toggenburg. By CARL SCHMIDT. *Bericht über die 38. Versammlung des oberrheinischen geologischen Vereins,* 1906, *pages* 39-45, *with* 3 *figures in the text.*

In going up from Güntenstall to the "brown-coal mine" on the road from Uznach to Gauen, the abandoned heapsteads of ancient coal-workings are seen to be quite numerous. According to the old laws of Canton St. Gallen, the minerals belong to the owner of the surface-soil, and thus, at as many as ten places on the hillside, coal has been more or less wastefully worked down to a certain depth, by ten different landowners. From the adits which have long fallen in, springs now flow, the waters of which are in part used up by neighbouring communes. At present only one mine is at work, situated at an altitude of 1,652 feet above sea-level, and duly indicated on the Swiss Ordnance Survey map. It was started in the year 1826, and comprizes an approximately horizontal adit about 2,235 feet in length, which winds about a good deal, since it practically boxes the compass. The coal-seam is from 3½ to 5 feet thick; towards the roof it gradually passes into what the pitmen term *silber* (silver), that is, it becomes more argillaceous, flaky, softer, and paler. This *silber,* which may attain a thickness of 20 inches, is used for packing: when exposed to the air outside the mine, it very soon crumbles away. The author had a good opportunity of examining a section of the floor in one of the working-places, and thereby confirmed the observation, made some years ago by a Zürich geologist, that the coal-seam is underlain by moraine. This moraine consists of yellowish sandy clays and gravel, containing polished and striated boulders of limestone and *verrucano,* varying in size from that of a man's fist to that of a man's head.

The workings are very dry on the whole, and they are ventilated by two shafts. The output is on the downgrade. A close examination of the coal shows it to consist largely of compressed and twisted branches and roots of plants, with occasional pine and fir-cones, etc. Very different views have been expressed as to the age of this brown-coal. According to some geologists, it is inter-glacial, and according to others undoubtedly post-glacial.

L. L. B.

GUADALUPANA MERCURY-MINE, SAN LUIS POTOSÍ, MEXICO.

Breves Anotaciones sobre la Mina de Mercurio "La Guadalupana," San Luis Potosí. By ALBERTO CAPILLA. *Memorias de la Sociedad Científica "Antonio Alzate,"* 1904, *vol. xiii., pages* 423-427.

This is said to be one of the richest mercury-deposits that are worked in Mexican territory, and the author's data were collected on a recent visit. The mine is about 19 miles distant by a good cart-road from the Moctezuma station of the Mexican National railway, and this distance will presently be diminished, by means of a new short cut, by fully 5 miles. The climate is healthy, labour is at once plentiful, skilled and cheap, and all the conditions are favourable to easy and economical working. The smelting-works are about 1¼ miles distant from the small borough of Moctezuma (and, consequently, 11¼ miles distant from the mine), as the works could not be set up in the neighbourhood of the mine itself owing to the deficiency of water-supply. On the other hand, transport is cheap, on account of the road being level practically all the way, and of the abundance of pasturage available for cattle.

There is a good *patio* at the mine, as well as assay-laboratories, store-

houses, etc., all compactly arranged. The deposit occurs among highly folded calcareous slates (or marls), and forms a belt from 20 to 33 feet broad, having much the appearance of a vein that strikes generally north and south, with an average dip of 55 degrees westward. But there is no precise evidence of the existence of a fissure, of which such a vein might be said to form the infilling. The ore consists entirely of cinnabar, which either impregnates the marls or shoots out in small leaders among them, and is associated with calcite and a certain amount of finely crystalline gypsum. The absence of all other sulphides but those of mercury is characteristic of this deposit, and is (on the whole) another circumstance which favours the working, even of low-grade ore. At the time of the author's visit a depth of nearly 500 feet had been reached, and the deposit had been followed for over 650 feet along the strike. So far as could be ascertained from exploration-work there was no diminution in the richness of the ore. The sump of the deepest shaft is pumped dry by means of a gasoline-motor, which vitiates horribly the atmosphere of the mine. Here the author takes occasion to point out that both the State and the municipalities appear to be quite indifferent to matters affecting the health and even the lives of the labouring-classes. The output, for reasons which are detailed, varies extremely, the mine producing sometimes in a single week what at other times it takes two months to get; and perhaps the next week the output will barely cover the expense of working. The average weekly output is 10 tons, assaying 10 per cent. of metallic mercury (at least other 10 per cent. being lost in the process of treatment). L. L. B.

EXPERIMENTS WITH SAFETY-EXPLOSIVES AT THE FRAMERIES EXPERIMENTAL STATION, BELGIUM.

Sur les Résultats obtenus au Siège d'Expériences de Frameries avec les Explosifs de Sûreté: Rapport présenté à la Commission du Grisou. By G. CHESNEAU. *Annales des Mines*, 1905, *series* 10, *vol. viii., pages* 407-419.

This memoir constitutes the official report presented to the French Fire-damp Commission. The author points out that the Frameries experiments have not imported any new element into the question of safety-explosives, as they are fundamentally a mere repetition of the experiments carried out between 1894 and 1897, at Gelsenkirchen in Westphalia, although they have, of course, been so extended as to include more recently-invented explosives. The consequence is, that the most important results obtained at Frameries are all but identical with those previously obtained at Gelsenkirchen. But, in the German experiments, much lower limiting-charges (that is, the charge up to which an explosive will certainly fail to ignite fire-damp) were obtained by firing cartridges in the free atmosphere, and the French Fire-damp Commission itself had previously pointed out that detonation in the open air was a far more rigorous criterion of the safety of explosives than detonation in a mortar. Now, in the Frameries experiments, the cartridges were always detonated in a steel cannon, with a hole 2·6 inches in diameter. Certain marked discrepancies between the results of those experiments and other experiments conducted with safety-explosives at Sevran-Livry and Liévin are pointed out, and reasons are adduced for preferring the basis from which the French experimenters start. Then it is observed that not a single one of the explosives manufactured and used in France was tried at Frameries, and this may help

in part to explain the rather sorry figure cut at the Belgian experiment-station by nitrate-of-ammonium explosives. On the other hand, there is reason to believe that the very high limiting-charges obtained by Mr. V. Watteyne at Frameries with complex mixtures would have yielded far less favourable results under conditions assuring more complete detonation. For instance, if the explosive had filled the mortar or cannon without leaving any empty spaces, it would have detonated more completely, as the experiments of the French Fire-damp Commission have shown; and this would have been more in accord with the usual practice of shot-firing in mines.

The Belgian Ministerial Circular of January 31st, 1905, which sets the seal of official sanction on the Frameries experiments, is adversely criticized. These experiments, like the older series carried out at Gelsenkirchen, have, it is true, lengthened the list of safety-explosives, but hardly justify the omission from that list of certain compounds recommended by the French Fire-damp Commission. On the other hand, the fears expressed by that Commission in regard to the inflammability of mixtures containing wheat-flour, rye-flour, or sawdust, are shown by both the Gelsenkirchen and the Frameries experiments to be greatly exaggerated, if not unfounded. The author, however, traverses diametrically the opinion expressed by the Belgian experimenters, that such mixtures are really more effective than nitrate-of-ammonium explosives. So far from agreeing with that contention, he maintains that the former are very much less effective. He concludes that the Frameries experiments are not of such a nature as to entail the necessity of any administrative action on the part of the French Department of Mines, and the Fire-damp Commission, adopting his conclusion, simply recommended the publication of his report.

L. L. B.

EXPERIMENTS WITH SAFETY-EXPLOSIVES.

L'Expérimentation des Explosifs de Sûreté. By J. Daniel. *Congrès International des Mines, de la Métallurgie, de la Mécanique et de la Géologie appliquées, Liége, 25 juin au 1er juillet, 1905 : Section des Mines, vol. i., pages* 285-289.

Prominent among the problems connected with the use of explosives in the presence of fire-damp and coal-dust, is the experimental determination of the degree of security possessed by so-called safety-explosives; but the results obtained at different testing stations, with the same explosives, show many variations. There can be no doubt that the appointment of an international commission for the experimental study of safety-explosives, conducted on uniform and practical lines, might render great service, the conclusions arrived at from such experiments having sufficient authority to show the danger of some explosives, while permitting the classification of others. The author proposes to make use of the testing-station at Frameries.

J. W. P.

TESTS OF EXPLOSIVES.

Les Lampes de Sûreté et les Explosifs au Siège d'Expériences de Frameries. By V. Watteyne and S. Stassart. *Chapitre iii. : Les Explosifs. Congrès International des Mines, de la Métallurgie, de la Mécanique et de la Géologie appliquées, Liége, 25 juin au 1er juillet, 1905 : Section des Mines, vol. i., pages* 228-272, *with numerous figures in the text.*

The tests have hitherto consisted in determining (*a*) the limit-charge, without stemming, of what were formerly regarded as safety-explosives and

of some others submitted for authorization; (*b*) the extreme charge, with stemming, of some of these explosives; and (*c*) their power.

The limit-charge was determined by ten tests that failed to ignite an explosive mixture. Ignition was first produced, and then the charge was gradually diminished by 1·76 ounces (50 grammes) for those above 7·04 ounces (200 grammes) and half for those below, until the limit-charge was reached.

The power of the explosives was measured by the Trauzl leaden block, 7·76 inches (197 millimetres) in diameter and 7·87 inches (200 millimetres) high, with a hole 0·98 inch (25 millimetres) in diameter and 4·72 inches (120 millimetres) long; and the standard was a charge of 0·35 ounce (10 grammes) of dynamite with 75 per cent. of nitro-glycerine, chosen on account of the simplicity and constancy of its composition. The power was measured by the equivalent weight, that is, the weight of the explosive tested that produces, under the same conditions, an enlarged recess equal to that formed by the standard charge. The tamping was effected by 1·22 cubic inches (20 cubic centimetres) of fine, dry sand, covered by slightly damped clay, and closed in by an iron plate with wooden wedges.

The limit-charge being known, and the equivalent weight determined, it was easy to deduce the equivalent charge, expressed in a standard explosive (dynamite I.), of each explosive's limit-charge, which gives the true value of a safety-explosive.

It was also considered useful to ascertain the mass of rock that could be brought down, in ripping roofs and floors, by a charge equivalent to the limit-charge. It was found, as the result of many experiments, that in compact rock charges of 10·58, 14·11 and 17·64 ounces (300, 400 and 500 grammes) brought down about 26·48, 35·32 and 61·80 cubic feet (0·75, 1 and 1·75 cubic metres) respectively. By means of this ratio the approximate average quantities of rock that can be brought down by the limit-charges of the various safety-explosives were calculated.

The favourable influence, as regards safety, of an increased percentage of ammonium nitrate is confirmed. The calculated temperature of detonation, although constituting a valuable element of investigation, cannot alone measure the degree of safety. The safety of an explosive does not depend upon its chemical composition alone, but also on the method of its manufacture.

Stemming of slight length, lightly inserted, greatly increases the degree of safety, and this result varies with the nature of the explosive, being least with ordinary high explosives and relatively slight with mixtures of nitro-glycerine and ammonium nitrate; but, on the contrary, it is greatest in explosives containing a large proportion of ammonium nitrate without nitro-glycerine.

J. W. P.

EXPERIMENTS ON THE SENSITIVENESS OF NITRO-GLYCERINE EXPLOSIVES, ETC.

Versuche zur Prüfung der Empfindlichkeit gefrorener und halbgefrorener Nitroglyzerinsprengstoffe gegenüber plastischen. *By* PROF. W. WILL [AND OTHERS]. *Zeitschrift für das Berg-, Hütten- und Salinen-wesen im Preussischen Staate,* **1905**, *vol. liii., pages* 21-56, *with* 4 *figures in the text.*

In his first report, of March 28th, 1903, Prof. Will states that a recent accident had suggested once more the question whether nitro-glycerine explosives became more dangerous under the influence of cold. Many

attempts had been made in former years, both in Germany and in this country, to solve the problem, and it is not claimed that the experiments here recorded have by any means exhausted the possibilities of the case, although, perhaps, they carry us a little way farther towards a definite solution.

At the Central Research Laboratory at Neubabelsberg, the material forming the subject of experiment consisted of (1) guhr-dynamite, containing 75 per cent. of nitro-glycerine; (2) gelatine-dynamite, containing 65 per cent. of the same; and (3) blasting-gelatine, containing 8 per cent. of nitro-cellulose. The tabulated results confirm the generally received opinion that guhr-dynamite, when frozen hard, is less sensitive to all sorts and degrees of rough handling, to impact by shock or blow, than the same explosive in a thawed or unfrozen (plastic) condition. With regard to gelatine-dynamite and blasting-gelatine (although, on the whole, they prove to be less sensitive than guhr-dynamite, whether in the frozen or in the plastic state), when they are considered by themselves, the difference of sensitiveness as between the frozen and the plastic state does not come out quite so clearly. Thus, hard-frozen gelatine-dynamite, irrespective of the quantity with which the experiments were made, showed greater sensitiveness than the still plastic material at temperatures between 32° and 41° Fahr., but was less sensitive than the same explosive warmed up to a temperature of 77° Fahr. Moreover, in the course of thawing a given quantity of gelatine-dynamite, the sensitiveness was found to decrease first of all, and then to increase again. In comparison with this explosive, blasting-gelatine approximates in sensitiveness more nearly to guhr-dynamite: when hard frozen, or even half frozen, it proved throughout less sensitive than when thawed or plastic. These last-mentioned results, differing somewhat as they do from those obtained in Great Britain with the same explosive, appear to require further investigation. It is noteworthy that guhr-dynamite freezes with great facility, gelatine-dynamite far more slowly, and blasting-gelatine slowest of all. It would seem as if the rate of freezing is not altogether without influence on the ultimate sensitiveness of the frozen explosive.

In a second report, dated June 11th, 1904, Prof. Will records a further series of experiments, first of all with nitro-glycerine alone: once more was it proved that this substance is less sensitive to any shock or blow when in the frozen state than it is when fluid. The further experiments with guhr-dynamite confirmed the results obtained in the first series of experiments. Moreover, the attempt to increase the percussive energy by kneading the material into appropriate shapes, failed of its effect, as the frozen dynamite was shattered to bits without exploding. Nor did a repetition of thawing and freezing appear to increase the sensitiveness of the explosive. Experiments conducted with blasting-gelatine containing 92 per cent. of nitro-glycerine showed that in any shape or condition it is more sensitive than frozen, and less sensitive than unfrozen, guhr-dynamite; also, that the difference in sensitiveness between frozen and plastic blasting-gelatine is considerably less than than between frozen and plastic guhr-dynamite. Repetition of thawing and freezing had no perceptible influence in this case either; but, in the shooting-tests with a rifle, blasting-gelatine proved unmistakably more sensitive in the hard-frozen than in the plastic condition, while experiments made with falling weights, etc., led to the contrary inference. Gelatine-dynamite, of the same composition and manufacture as that tested in 1903, was shown to be more sensitive than blasting-gelatine in the thawed state; but, whether frozen or unfrozen, it proved less sensitive than plastic guhr-dynamite or hard-frozen blasting-gelatine.

When frozen, gelatine-dynamite would appear to be more sensitive than in the thawed state; its behaviour, when frozen, is, however, very erratic. On the whole, the degree of sensitiveness varies even less as between frozen and unfrozen gelatine-dynamite than between frozen and unfrozen blasting-gelatine. Experiments made, in order to see in how far the former explosive is affected by being kept in store, showed that, owing to the hygroscopic properties of cellulose, the material undoubtedly absorbs moisture from the ambient atmosphere.

Summarizing the results of both series of tests, Prof. Will concludes that the fear that these explosives are more dangerous in the frozen than in the thawed state has found no justification, and that the rules universally enforced in regard to the handling and packing of the different varieties of dynamite should apply equally well to them when frozen as when not.

The Royal Mining Bureau of Saarbrücken caused a succession of tests to be made at the Neunkirchen experimental station in 1904 and 1905, with guhr-dynamite, gelatine-dynamite, blasting-gelatine, and gelatine-carbonite (the last-named containing 25·3 per cent. of nitro-glycerine, 41·5 of nitrates, and 25·6 of common salt). The first series of experiments showed that, in the frozen state, nitro-glycerine explosives are generally far less sensitive to shock than when plastic. Also, that by freezing and then thawing the cartridges again, decomposition of a kind sets in—a fair amount of nitro-glycerine separating out. More extensive experiments, in 1905, showed that, at temperatures of 44° and 46° Fahr., guhr-dynamite freezes much more quickly than the gelatinous nitro-glycerine explosives. On the other hand, blasting-gelatine (consisting simply of gelatinized nitro-glycerine) freezes with far greater difficulty than those gelatinized explosives which contain other constituents in the form of powder. At 44° or 46° Fahr., blasting-gelatine apparently will not freeze at all. Gelatine-dynamite of all kinds, if submitted over and over again to the freezing-process, would appear to solidify more quickly than when quite fresh made. At temperatures of 50° to 51° Fahr. and over, none of the explosives froze, nor did they show any sign of freezing after having been laid on the shelf for eleven days. Further experiments, directed to prove decomposition after successive freezing and thawing, only showed that a small quantity of a clear liquid sweated out of the nitrated explosives, which might contain a very small amount of nitro-glycerine. It was found that none of the explosives, once frozen, would thaw at a temperature of less than 51·8° Fahr. Tests in the Trauzl leaden mortar showed that gelatine-dynamite loses in shattering power as a result of freezing. Elaborate tables are given, embodying the results of experiments with the "falling hammer," the explosives being placed on a small anvil below it. In all cases the frozen explosives proved less sensitive than those in the plastic state, and it was very difficult to get any explosion at all with the safety-explosives.

L. L. B.

THE FRENCH OFFICIAL REPORT ON THE EFFECT OF DETONATORS.

Commission des Substances Explosives: Rapport sur l'Étude des Effets des Détonateurs en raison de leur Composition fulminante. [OFFICIAL.] *Annales des Mines*, 1904, *series* 10, *vol. vi., pages* 125-150, *with* 5 *figures in the text.*

By a rescript under the date of May 23rd, 1903, the French Minister of War submitted the following question for the consideration of the Commission on Explosives:—Whether the detonators supplied in the usual

course of trade, frequently containing substances (such as picric acid) other than pure fulminate, can produce effects equivalent to those obtained with detonators consisting of pure fulminate. A letter from Mr. Henri Le Chatelier, one of the members of the Fire-damp Commission, accompanied this rescript, and drew attention to the untoward consequences which frequently result from miss-fires in fiery mines, pointing out that many of these miss-fires are attributable to the inferior quality of the detonators in use.

The Commission proceeded to analyse, at the Central Gunpowder Laboratory, 15 varieties of detonators, with a view of determining their chemical composition. These belonged to the following four groups: (1) detonators made of pure fulminate; (2) German type of chlorated fulminate; (3) mixed type, pure fulminate with picric acid; and (4) German mixed type, chlorated fulminate with picric acid. Their effects were then compared in two series of experiments: (1) by detonating them in an unconfined atmosphere on leaden sheets, and (2) by detonating them within leaden blocks. Detailed descriptive tables are given, as also diagrammatic curves expressive of the results. Not content, however, with this theoretical comparison (as they term it in their report), the Commission proceeded to make a practical comparison of the same varieties of detonators, by using them to fire off cartridges filled with nitrate-of-ammonium explosives, and also leaden tubes containing nitrate of ammonium only. The reason for selecting this particular chemical compound was, because Mr. Le Chatelier had especially mentioned ammonium-nitrate explosives as giving rise to frequent miss-fires in fiery mines. The results confirmed those obtained in the theoretical experiments, showing that detonation on leaden sheets, preferably supplemented, perhaps, by detonation within leaden blocks, furnishes a fairly exact criterion of the efficiency of the detonators tested. The regularity of their effects is measured with sufficient accuracy by detonation within leaden blocks.

With regard to efficiency, the experiments show that mixed detonators are by no means inferior to those which consist of pure fulminate. With regard to regularity, some detonators are very defective: those of the German mixed type (fulminate of mercury, chlorate of potassium and picric acid) proved irregular in all the tests, and even gave rise to one miss-fire. Those of the mixed type (pure fulminate with picric acid), and those containing only 12 grains or so of pure fulminate, exhibited but little regularity when detonated within leaden blocks, or when used to explode ammonium nitrate contained in leaden tubes. The Commission, therefore, concluded that, for practical purposes, it is of greater importance to have some check on the regularity of detonators rather than to prescribe any particular selection of fulminating mixtures. Every detonator, however, should bear a label indicating the weight and nature of the fulminating material, in order to obviate the unchecked introduction of mixtures the efficiency of which has not been previously tested. L. L. B.

SINKING TWO VENTILATING SHAFTS IN THE BRUCH COAL-MINE.

Ueber das Abteufen zweier Wetterschächte im Brucher Grubenfelde der Gewerkschaft Brucher Kohlenwerke in Bruch. By A. PADOUR. *Österreichische Zeitschrift für Berg- und Hutten-wesen*, 1903, *vol. li., pages* 29-33, 46-49 *and* 63-68, *with* 4 *illustrations in the text and* 2 *plates.*

Work was begun in July and October, 1900. The upcast was sunk to a depth of 1,362 feet by December, 1901, that is, in 372 days. The downcast

took much longer, because, for 200 feet, water percolated through the walling into the shaft. It was caught by water-rings and pumped, at first by hand, and afterwards by a duplex steam-pump. At a depth of 70 feet, the walling was two bricks thick, the space left between them being filled with concrete, but it was not found effectual in keeping back the water.

The shafts were sunk to a depth of about 1,260 feet through grey clay, with four or five coal-seams, 6 feet thick, at a depth of 200 feet. The shafts were sunk by hand, and then by blasting. From six to eight holes, 1¼ inches in diameter, were filled with gelatine-dynamite, and fired with Bickford fuse. The total quantity used for the two shafts was 2,700 pounds, and about 2,000 shots were fired in each. The shafts were provisionally fitted with iron or wooden cribs, about 3 feet apart, connected by props and bolts, and backing deals. The shaft was lined with wedge-shaped bricks, to fit the periphery, and two cradles were used at a time. Naked lights were at first allowed, and safety-lamps were only used when within 12 feet of the coal-seams. Thirty-nine men were employed in the downcast, and thirty-six in the upcast shaft, working in shifts of 8 and 12 hours. The normal rate of work per day was 3·6 feet with single-brick, and 2·9 feet with double-brick, walling. The total cost in wages and material was £11 4s. in one, and £13 1s. in the other shaft, per foot of shaft sunk.

The ventilation of the mines was produced by two double-inlet Schiele fans, 11½ feet in diameter, each delivering 140,000 cubic feet of air per minute at a water-gauge of 1½ inches. They were belt-driven by electric motors, and their speed could be varied from 160 to 190 revolutions per minute according to the volume of air required. As a rule, one fan only is used, the other being held in reserve. The inlets of the fans can be closed by iron doors, mounted on a vertical shaft, and manipulated by means of a horizontal lever placed outside the building. E. M. D.

FALL OF SIDE IN A SHAFT IN UPPER SILESIA.

Das Unglück im Jelkaschacht des Steinkohlenbergwerks Preussen bei Miechowitz O.-Schl. am 1. März 1905. By -- HOHNHORST. *Zeitschrift für das Berg-, Hütten- und Salinen-wesen im Preussischen Staate*, **1905**, *vol. liii., Abhandlungen, pages* 502-507, *with* 4 *figures in the text.*

The disaster occurred at the Preussen colliery, belonging to Count Thiele-Winckler, at Miechowitz, in the Beuthen coal-field. Three borings, put down in the years 1899-1900, had struck the Coal-measures at, respectively, 544½, 662½ and 544½ feet from the surface, and were stopped respectively at the depths of 2,640 feet, 2,752 feet and 3,122 feet. In each case, the Pochhammer coal-seam, the basement-seam of the Sattelflötz group (remarkable for the number, thickness and excellent quality of the seams included therein) was struck. The lie of the strata being thus determined, it was resolved to start sinking at the southernmost boring, because at that point were found united the conditions most suitable for the purpose. The Winckler shaft was sunk at the bore-hole itself, and the Jelka shaft (where the accident herein described occurred) 213 feet supposedly due west of it. Both shafts are circular and intended for coal-drawing, while a third shaft is projected in the northern district of the colliery.

On March 1st, 1905, the walling (two bricks thick) of the upper portion of the Jelka shaft had been completed: but, from the depth of 967 feet down to the sump below the 1,214 feet level, it was lined provisionally with

timbering; and the masons were about to build the walling from the bottom of the shaft to below the 1,050 feet level, when, at 9 p.m., heavy masses of rock crashed in, demolishing shaft-rings and scaffolding, hurling down the shaft and burying, among the débris, 18 human beings, no less than 15 of them being killed, while 3 suffered more or less severe injury. The two pumps which kept the sump free of water were involved in the general ruin, but of the 15 persons who were engaged on the masonry-work, 6 managed to escape uninjured.

The strata between the 1,050 feet and the 1,214 feet levels were of a very unyielding character, and blasting had to be resorted to in order to make progress through them; they dip from 18 to 19 degrees northward. The shaft was rather wet, the inflow of water averaging from, say, 66 to 88 gallons per minute. The water flowed along the 1,214 feet level to the Winckler shaft, through which it was drawn to bank. The timbering was of stout pine, and none had been used before for any purpose whatsoever. Cribs, consisting of twelve-segment polygons, were generally placed about 5 feet apart; and, judging from the details given as to supports, fastenings, etc., every precaution that experience and knowledge could suggest seems to have been taken to make tubbing, staging, and other structures within the shaft as solid and safe as possible. In addition to ordinary pit-lamps, electric arc-lamps of 1,000 candle-power were used to light up the scene of operations.

After everything had been made secure for the rescue-parties, the recovery of the bodies of the victims was proceeded with, and was completed on March 9th, 1905.

The mass of clay-slate which had crashed into the shaft must have exceeded 70 tons, and it took 116 wagon-loads of 24¾ cubic feet capacity to clear the stuff out of the sump. In the broken-down portion of the shaft, an argillaceous layer, not 3 inches thick, was detected in the strata, having now the character of a soft mud; whereas those who had observed it during the sinking operations averred that it was then tough and dry. Evidently the water-drip in the shaft had softened and disintegrated this layer. Dry or wet, however, this slippery layer played a part in the catastrophe, for it appears certain that the great loosened block of clay-slate glided along it, following the dip of the beds, and (striking the lining tangentially) twisted the crib-rings outwards, and thus deprived the staging of its supports. L. L. B.

FALL OF SCAFFOLDING IN A SHAFT IN WESTPHALIA.

Der Bühnenabsturz im Schacht V der Zeche General Blumenthal am 28. September 1904. By — SCHNEPPER. *Zeitschrift für das Berg-, Hütten- und Salinenwesen im Preussischen Staate*, 1905, *vol.* liii., *Abhandlungen, pages* 15-18, *with* 3 *figures in the text.*

On February 5th, 1904, the sinking of an upcast-shaft was begun for the western district of the General Blumenthal colliery, at Recklinghausen. Down to a depth of 287 feet, the sinking was accomplished by hand-labour, without shot-firing, and the shaft was lined with watertight tubbing. At the depth mentioned, the comparatively waterless, tough, grey marls were entered, and thenceforward it was found necessary to have recourse to blasting in order to carry on the sinking. As work progressed, the lining of the shaft was continued, in the shape of a wall 1½ to 2 bricks

thick, with a clear diameter of 16½ feet: at every interval of 4½ feet or so, two oaken beams, 16½ feet long and 7½ by 9½ inches in cross-section, sloping at a high angle, were let into the wall for the length of a foot at both ends, leaving a clear length of beam of 14½ feet: they were used temporarily as the main supports for the wooden scaffold upon which the masons worked at the walling of the shaft. Meanwhile, the sinking had reached a depth of 722 feet, and by September 28th, 1904, the walling was completed to within 20 feet. The third shift of 13 masons started work at 6·0 a.m., and, at 7·30 a.m., a kibble laden with bricks suddenly crashed through the northern oak-beam; thereupon five out of the six sections of which the scaffold was built gave way, hurling to the bottom of the shaft ten men, together with planks, hods, bricks, and other materials. Only the sixth semi-circular, or rather lunate section of the scaffold, upon which three men were standing, remained in place undamaged. A shower of fragments of marl kept falling from the still unwalled sides of the shaft, and a fairly large piece of walling was forced inward by a mass of rock which had fallen between it and the side of the shaft. Owing to various difficulties which are recited, the rescue-party was not able to bring to bank the bodies of the ten victims until 5·0 a.m. the next day.

It is reckoned that the total weight resting upon the above-mentioned pair of oaken beams, immediately before the disaster, amounted to 102 cwts.; but it is pointed out that this figure should, in reality, be halved, as the strain on the beams was relieved by certain flat-iron supports let into the wall, upon which the scaffold was also carried. However, it seems probable that the actual margin of safety was a little less than that here calculated. On examination of the broken beam, it was found that it had been sawn against the grain, or transversely to the fibres of a given stem or trunk instead of parallel with them, and this undoubtedly constituted a source of weakness. Official enquiry showed that the management had always been very careful in the selection and testing of the timber, but with such rough-sawn beams it was by no means easy to detect the direction of the grain. Although no blame is attributed to the management, the Royal Mining Bureau at Dortmund has issued additional regulations as to the precautions which are to be observed in future when erecting scaffolding in shafts. L. L. B.

A PROCESS FOR CONSOLIDATING TUBBING AND RENDERING IT WATERTIGHT BY THE INJECTION OF CEMENT.

Notice relative à un Procédé pour rendre étanches et consolider les Cuvelages par Injections de Ciment. By Henri Portier, 1900.

It happens frequently, not to say always, in spite of all care taken in the selection of material and the insertion of tubbing, that after a while infiltrations of water show themselves, either in the form of sweating or of more or less powerful jets of water. These leakages of water can be stopped temporarily by wedging, often under great difficulties. Their unexpected appearance renders it necessary to keep special workmen always on the spot, and causes stoppages during working hours, and, in consequence, a decrease of output. This water is added to that coming from the workings, and involves the employment several times a week, and often daily, of a winding-engine or of an underground pumping-engine.

The tubbing of No. 3 shaft of the Courrières collieries was in particularly bad condition. Frequent wedging had enlarged the joints in places to such an extent that it had become almost impossible to close them, and they had been protected with plates bolted to the tubbing and made tight by sheets of indiarubber. Fragments often flew off from the tubbing, thus necessitating the complete replacement of portions. Such replacement always demanded a long and troublesome operation, accompanied by a heavy flow of water, and necessitated the cutting out of places in the concrete, and even in the solid rock, in order to insert the new segments. As it was impossible to multiply too greatly these hollows, the entire re-tubbing of the pit at an early period was being considered, although it would entail the consequence of laying the pit idle for about a year and a very costly operation.

Under these conditions, the writer proposed, in March, 1899, to try the injection of cement behind the tubbing. After various trials to see whether it might be possible to force cement-slurry by means of pumps into a space where the pressure exceeded 8 atmospheres, the following system, which demands but little labour and a simple installation without special apparatus, was adopted. It enables the work to be carried out with extreme rapidity and without in any way interfering with regular winding operations.

The static level of the water being about 39½ feet (12 metres) below the level of the ground, the apparatus was installed at the surface. It consisted of a tank of about 33 gallons (150 litres) capacity, fitted with a continuous supply of water. To the bottom of this tank was attached a column of iron pipes, 1·18 inches (30 millimetres) in internal diameter, terminating in an indiarubber hose of sufficient strength to resist an internal pressure of 9 atmospheres, and screwed to a tap fixed to the tubbing at the point where the injection was to be made. The upper portion of the column of pipes was connected by a branch to the delivery pipe of a hand-driven force-pump; and another pipe was inserted so as to allow the air to escape. The taps attached to the tubbing were fitted by means of straps and made tight by an indiarubber washer; the other end of the tap terminated in a screw-thread with which it was connected to the indiarubber hose. The hole through the tap was round, so that a drill, 0·6 inch (15 millimetres) in diameter, could go through it. Once the tap was fixed, the tubbing was pierced by the drill, the tap was then closed and connected with the column of pipes. All the taps could then be opened; the air escaped through the escape-pipe, and the syphon formed by the column connecting the tank with the rear part of the tubbing was filled automatically.

After the escape-pipe and the delivery-pipe of the force-pump were closed, slow-settling Portland cement, well screened, was rubbed up in the tank, and it was kept constantly stirred up so as to prevent any settling. The thickness of the slurry thus formed was regulated by the rapidity of the current, it being made thinner as the speed diminished. The hand-pump, which was always kept full of water, was only used when there was reason to fear any obstruction in the pipe or any premature stoppage behind the tubbing. The tap of the tank was then closed and that of the pump opened, the hand-pump being worked for a few minutes. It was only rarely necessary to have recourse to this operation. When the current was almost stopped on account of the obstacle to the passage of the water, the tap fixed to the tubbing was closed, and the pipe-column was detached from

it to enable a stream of clean water to be run through the latter. The same precaution had, moreover, to be taken every time that the work was stopped for any reason whatever, even if only for a moment. After 24 hours, the tap attached to the tubbing could be removed, without there being the least need of plugging the hole.

This operation was performed successively at the head of each ring of tubbing, in two places diametrically opposite, beginning at the bottom. Altogether, 1,010 bags of cement, weighing 110 pounds (50 kilogrammes) each, were used in a length of 282 feet (86 metres). At times, especially at the commencement of operations, the current had sufficient velocity to allow 40 bags to be introduced per hour. The whole work took 20 days, including the erection and removal of the machinery. The working time was 10 hours per day.

Two labourers and two trained workmen were employed. One labourer was engaged all the time in stirring up the water in the tank, and was relieved by the other labourer and by one of the workmen, so as to keep the cement well rubbed down. The other workman was in the shaft, ready to work the taps and to detach the pipes at the agreed signal. He also watched for any jets of water, and plugged those that appeared.

The cost of the work was about as follows:—

	Francs.	£	s.	d.
2 workmen at 6 francs per day for 20 days	240	9	12	0
2 labourers at 4 ,, ,, ,,	160	6	8	0
50,500 kilogrammes of cement at 3·60 francs per 100 kilogrammes	1,818	72	14	5
Taps, tanks, pipes, etc.	282	11	5	7
Totals	2,500	£100	0	0

This cost was relatively insignificant compared with the results obtained. The flow of water, through the tubbing, which attained an average of 83,600 gallons (3,800 hectolitres) per 24 hours, had been entirely stopped to such an extent that holes have been drilled, near the top of the tubbing, of considerable length in order to get water sufficient to keep it damp enough for its good preservation.

It will be understood, moreover, that the joints of the tubbing, the holes and crevices in the masonry of the surrounding strata have been filled with cement; and, these various parts being thus closely connected together, the strength of the shaft is greatly increased. Finally, there is every reason to suppose that the results obtained will be permanent, for no change has been visible during the seven months since the work has been completed; on the contrary, it appears as though the pit, if possible, were becoming drier. A similar operation has been performed at three other pits of the Courrières collieries, and it will be undertaken at other pits when necessary. In each of these pits the flow of the water through the tubbing has been completely stopped.

The following are the quantities of cement employed and the flow of water stopped in each shaft:—

Name of Shaft.	Bags of Cement Employed.	Flow of Water per 24 Hours.	
No.	No.	Gallons.	Hectolitres.
2	632	Has not been measured.	
3	1,010	83,600	3,800
5	1,494	28,600	1,300
8	1,890	27,990	1,270

A. B. C.

THE APPLICATION OF DIRECT-CEMENTATION TO SHAFT-SINKING.

Cimentation des Terrains aquifères en vue du Creusement des Puits. By H. PORTIER. *Congrès International des Mines, de la Métallurgie, de la Mécanique et de la Géologie appliquées, Liége, 25 juin au 1er juillet, 1905: Section des Mines, vol. i., pages* 419-439, *with* 4 *figures in the text and* 1 *plate.*

The quantities of cement injected behind the tubbing were generally greater than the probable volume of the spaces in the concrete-backing, so that a portion must have penetrated into the measures, as was indeed manifested in many ways. Various observations led to the supposition that, by forcing liquid cement into the fissures of the rocks until no more would penetrate, a sufficiently extensive zone might be consolidated so as to be rendered watertight; and this supposition has been confirmed by the works of consolidation that have been carried out during the last few years.

As a consequence, the cementation-method was applied in 1904, for the first time, to consolidate the water-bearing measures through which the No. 11 shaft of the Béthune collieries was being sunk. The shaft had a clear diameter of 17·06 feet (5·2 metres); and, within this area, four holes for the cement-injection were bored, being distributed over two diameters at right angles, and about 5 inches (12 centimetres) from the inside of the future shaft. The water-tightness of the top of the measures was ensured by boring a hole, 19·68 inches (500 millimetres) in diameter, to a depth of 42·81 feet (13·05 metres) the upper part being tubed, and then, along the same centre-line, boring the definite hole, 11·81 inches (300 millimetres) in diameter, to a depth of 123·85 feet (37·75 metres). Tubing, 46·59 feet (14·2 metres) long, was inserted at the top of the hole; and the annular space between the two tubes was filled with a mixture of sand and cement.

The first injection of liquid cement was made at the bottom of the hole, on May 17th, 1904, but the water-level had not been reached. As the water of the cement might be rapidly absorbed by the chalk, so as to leave a cement-plug in the bore-hole, the measures were damped by sending down 5,280 gallons (24 cubic metres) of water, after which cement was injected. At first, a mixture of 1 part by volume of cement to 10 parts of water was employed; but, as the absorption diminished, so also did the cement-content, until it became only 1 part to 20 parts, the pump being used for continuing the injection. When the liquid cement rose so as to return to the tank on the surface, the injection-tubing was flushed with water and taken out for deepening the bore-hole, the cement-deposit at the bottom of the hole being first removed by the bell.

As a rule, the cement penetrated and set well in fissures of any importance, and chiefly in the vertical; but, on the contrary, in narrow, and especially horizontal, fissures it penetrated indifferently, or remained of a pasty consistence. The removal of the mud from these fissures may be effected by two methods, one by sending down a strong flush of water for driving it into the measures, as far as possible from the bore-hole; but reasons are given for rejecting this method. The other, which is likely to afford good results, consists in withdrawing the mud from the bore-holes by a pump.

The cementation-method is proposed, not as superseding others, nor as capable of solving all the difficulties due to water, but as being economical of time and money. J. W. P.

II.—REPORT OF THE CORRESPONDING SOCIETIES' COMMITTEE OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, SOUTH AFRICA AND LONDON, 1905.*

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The Committee beg leave to report that, at several meetings during the past session, they have had under consideration the suggestions with reference to Corresponding Societies which were brought forward by Principal E. H. Griffiths at the Conference of Delegates at Cambridge last year. In accordance with a resolution passed at that meeting, and sent up to the Committee of Recommendations, the General Committee of the Association appointed a Committee, consisting of certain members of the Council, with representatives of the Corresponding Societies, in order to consider the present relation between the British Association and the local scientific societies, with power to make suggestions for the greater utilization of such relationship. This Joint Committee duly reported to the Council of the Association, and their Report was remitted by the Council to the Corresponding Societies' Committee. The recommendations in the Report were discussed and amended by this Committee, and were finally adopted, in the amended form, by the Council.

As a result of this discussion, there will henceforth be two classes of local societies eligible for relationship with the British Association. One class, to be called *Affiliated Societies*, will consist, as at present, of such societies as undertake local scientific investigation and publish the results. Each Affiliated Society may be represented at the meetings of the British Association by a delegate, who must be a Member of the Association, and who will be, for the time being, a member of the General Committee. The new class of corresponding societies, to be called *Associated Societies*, will include societies formed for the purpose of encouraging the study of science, which have been in existence for at least three years and number not fewer than fifty members. Each Associated Society will have the right to appoint a delegate to attend the Annual Conference. This delegate, who may be either a Member or an Associate of the British Association, will have all the rights of a delegate from an Affiliated Society, except that of membership of the General Committee.

With regard to the suggestion made in the Chairman's Address to the delegates at Cambridge, that a *Journal of Corresponding Societies* should be established, the Committee, after very careful consideration of the subject, came unanimously, though regretfully, to the conclusion that, in their opinion, the publication of such a *Journal* by the British Association would be impracticable.

The question of obtaining, if possible, reduced railway-rates for members of local scientific societies when travelling even singly for scientific purposes, was referred to this Committee by the delegates at the Cambridge Conference.

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A form of application to the various railway-companies has, consequently, been drafted and distributed to all the Affiliated Societies, with the view of ascertaining their opinion. This application has been generally, but not unanimously, approved, and it now remains for the Committee to submit the matter to the Council of the Association before further action can be taken.

In view of the visit of the British Association to South Africa, it has been felt that the most convenient course to adopt this year would be to hold the Conference of Delegates in London after the South African meeting. This suggestion has been approved by the Council, and it has consequently been arranged that the Conference shall be held on October 30th and 31st, the latter being the date of a meeting in London of the General Committee of the British Association, which the delegates of the Affiliated Societies have a right to attend.

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The following Corresponding Societies nominated delegates to represent them at the Conference:—The Institution of Mining Engineers, Mr. J. A. Longden; the Manchester Geological and Mining Society, Mr. William Watts; the Midland Counties Institution of Engineers, Mr. J. A. Longden; the Midland Institute of Mining, Civil and Mechanical Engineers, Mr. Arnold Lupton; the North of England Institute of Mining and Mechanical Engineers, Mr. A. R. Sawyer; and the South Staffordshire and East Worcestershire Institute of Mining Engineers, Mr. A. R. Sawyer.

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First Meeting, October 30th, 1905.

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The Law of Copyright as affecting the Proceedings of Scientific Societies.

Mr. W. Morris Colles (Director of the Authors' Syndicate) said that from the proof of " Papers relating to the Question of Copyright " which had been placed in his hands since he entered the room, he gathered that the points which called for discussion were, mainly, the relations between scientific societies, their members, and the public, with reference to papers communicated to, and printed by, or delivered before the societies. These naturally resolve themselves into two classes, namely, public and private. As regards papers which were published in the general sense, by being placed on sale, the ordinary rules of copyright law applied; but papers which were only privately printed were indistinguishable from papers existing only in manuscript, as they were not published at all, and the copyright, unless assigned, remained in the authors by common law.

Some of the societies had, he noticed, bye-laws declaring the copyright of all accepted papers to be vested in them, but it was questionable whether these bye-laws were in themselves sufficient to give the societies a good title to the copyright in such papers without an actual assignment (which could be prepared by their legal advisers) in such a form as to hold good either against the members themselves or against infringers. This was,

in short, a case like so many arising under the Copyright Acts, which could only be met by special contract. Neither section 18 of the Copyright Act of 1842, nor the clauses of the Copyright Bill of 1900, affecting "collective works," could be held to apply. It had been suggested that scientific societies should endeavour to procure some special legislation when the Bill of 1900 was proceeded with; but Mr. Colles expressed it as his opinion that it would be found impracticable to obtain any additions to the Bill of 1900 that would meet the case, and he believed that it would still be found necessary to deal with this question as a matter of special contract outside the statutes. The temper of Parliament towards the copyright question was such that it was always peculiarly difficult to obtain exceptional rights, nor were such rights capable of being easily defined or made generally applicable.

Mr. Harold Hardy dealt with the position of the author of a paper which might be read at a meeting of a scientific society. This, he said, was partly affected by the law of copyright in books, and partly by the law relating to copyright in lectures. While the paper was unread or unpublished the author was entitled to copyright in his literary composition, and could restrain anyone from publishing it: he was in the same position as the author of a book in manuscript. Again, when the paper was read before the society, if the audience consisted merely of members of the society, or a limited number of persons invited and admitted by ticket, that was not regarded in law as publication, and the author would still be entitled to copyright, as in an unpublished manuscript. If, however, a paper was read before a meeting to which the public generally were admitted, the author could only protect his copyright by adopting one of two methods recognized by the law. He could, of course, print and publish his paper before oral delivery, and register it as a book at Stationers' Hall. In that case he would enjoy the same copyright as that which attaches to a published book. Another method was a very curious provision of the law, and one which was unreasonable at the present day. The law provided that if the author gave two days' notice to two magistrates living within 5 miles of the place where the paper was to be read, he would have protection for his copyright in the work for twenty-eight years. That was a provision which was generally unknown and consequently ignored. It was a senseless provision, because it imposed no duty upon the magistrates to take any steps with regard to the notice. They might lock it up in the pigeon-holes of their desks, and, instead of its being a warning to the public that the author's rights were preserved, the public generally knew nothing at all about it. This notice to the magistrates, therefore, ought to be abolished, and he was glad to find that the recommendation of the Royal Commissioners with regard to it had been adopted in the new Copyright Bill. Another amendment he suggested was, that the law should give protection for the oral delivery of lectures. A lecture might be described as a literary composition adapted for communication to the public either by printing or by oral delivery. Both those qualities had a commercial value and ought to be protected; but at the present time there was no protection for the right of publishing a lecture by oral delivery as distinct from the copyright. The law relating to lectures should be made somewhat analogous to the law in respect of dramatic compositions. The author of a play had copyright and the right of representation in public. The right of representation of a play might be compared to the publication of a lecture by an oral delivery, or the "lecturing right," as it was called in the Copyright Bill of 1900.

Mr. J. A. Longden (representing the Institution of Mining Engineers) said that, so far as the *Transactions* of the Institution of Civil Engineers are concerned, they are safely guarded. The Institution has rules by which if anybody communicates a paper to it that paper becomes its property; but it appeared to the speaker that the reason why its papers are so safely guarded is because it takes an interest in the matter and follows it up. If anybody chooses to pirate the information which has been communicated, the culprit hears of it and is stopped. The Institution of Mining Engineers found it difficult to prevent people from pirating the information which had been communicated. He thought that the rules were almost identical in both societies, and it seemed to him that it [infringement] was largely a matter of laxity. But, so far as the British Association was concerned, he took it that the Association would rather the information was circulated than kept back.

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Second Meeting, October 31st, 1905.

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Committees appointed by the General Committee at the South African Meeting in August and September, 1905.

1.—Receiving Grants of Money.

Subject for Investigation or Purpose.	Members of the Committee.	Grants.
		£ s. d.
Seismological observations	[illegible]	40 0 0
To co-operate with the Committee of the Falmouth Observatory in their magnetic observations.	*Chairman.*—Sir W. H. Preece. *Secretary.*—Dr R. T Glazebrook. Prof. W G. Adams, Captain Creak, Mr. W. L. Fox, Prof. A Schuster, Sir A. W. Rücker and Dr Charles Chree.	50 0 0
To investigate the erratic blocks of the British Isles, and to take measures for their preservation.	*Chairman.* Dr. J E. Marr. *Secretary.*—Mr P F Kendall. Dr. T. G Bonney, Mr C. E. De Rance, Prof. W. J Sollas, Mr. R. H. Tiddeman, Rev S. N Harrison, Dr. J Horne, Mr. F M. Burton, Mr. J. Lomas, Mr A. R. Dwerryhouse, Mr J. W Stather, Mr. W. T Tucker and Mr F. W Harmer.	Unexpended balance
To study life-zones in the British Carboniferous rocks.	*Chairman.* -Dr J E. Marr. *Secretary.*—Dr Wheelton Hind. Dr F A. Bather, Mr G. C. Crick, Mr. A. H. Foord, Mr H. Fox, Prof. E. J. Garwood, Dr. G. J Hinde, Prof. P F Kendall, Mr. R. Kidston, Mr. G. W Lamplugh, Prof. G A. Lebour, Mr B. N. Peach, Mr A. Strahan, Mr. D. T. Gwynne Vaughan and Dr. H. Woodward.	Balance in hand.

1.—Receiving Grants of Money.—*Continued.*

Subject for Investigation or Purpose.	Members of the Committee.	Grants.
		£ s. d.
To enable Dr. A. Vaughan to continue his researches on the faunal succession in the Carbonif-rous Limestone of the south-west of England	*Chairman.*—Prof. J. W. Gregory. *Secretary*—Dr. A. Vaughan. Dr. Wheelton Hind and Prof. W. W. Watts.	15 0 0
To investigate and report on the correlation and age of South Africa strata and on the question of a uniform stratigraphical nomenclature.	*Chairman.*—Prof. J. W. Gregory. *Secretary.*—Prof. A. Young. Mr. W. Anderson, Prof. R. Broom, Dr. G. S. Corstorphine, Mr. Walcot Gibson, Dr. F. H. Hatch, Mr. T. H. Holland, Mr. H. Kynaston, Dr. Molengraaf, Mr. A. W. Rogers, Mr. E. H. L. Schwarz, and Prof. R. B. Young.	10 0 0
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Corresponding Societies Committee for the preparation of their report.	*Chairman.*—Mr. W. Whitaker. *Secretary.*—Mr. F. W. Rudler. Rev. J. O. Bevan, Dr. H. T. Brown, Dr. Vaughan Cornish, Dr. J. G. Garson, Principal E. H. Griffiths, Mr. T. V. Holmes, Mr. J. Hopkinson, Prof. R. Meldola, Dr. H. R. Mill, Mr. C. H. Read, Rev. T. R. R. Stebbing, Prof. W. W. Watts, and the General Officers of the Association.	25 0 0

2.—Not receiving Grants of Money.

Subject for Investigation or Purpose.	Members of the Committee.
The rate of increase of underground temperature downwards in various localities of dry land and under water.	*Chairman and Secretary.*—Prof. H. L. Callendar. Lord Kelvin, Sir Archibald Geikie, Prof. Edward Hull, Prof. A. S. Herschel, Prof. G. A. Lebour, Dr. C. H. Lees, Mr. A. B. Wynne, Mr. W. Galloway, Mr. Joseph Dickinson, Mr. G. F. Deacon, Mr. Edward Wethered, Mr. A. Strahan, Prof. Michie Smith and Mr. B. H. Brough.
The consideration of the teaching of elementary mechanics, and the improvement which might be effected in such teaching.	*Chairman.*—Prof. Horace Lamb. *Secretary.*—Prof. J. Perry. Mr. C. Vernon Boys, Profs. Chrystal, Ewing, G. A. Gibson, and Greenhill, Principal Griffiths, Prof. Henrici, Dr. E. W. Hobson, Mr. C. S. Jackson, Sir Oliver Lodge, Profs. Love, Minchin and Schuster and Mr. A. W. Siddons.
The collection, preservation, and systematic registration of photographs of geological interest.	*Chairman.*—Prof. J. Geikie. *Secretary.*—Prof. W. W. Watts. Dr. T. G. Bonney, Dr. T. Anderson, Profs. E. J. Garwood and S. H. Reynolds, and Messrs. A. S. Reid, W. Gray, H. B. Woodward, R. Kidston, J. J. H. Teall, J. G. Goodchild, H. Coates, C. V. Crook, G. Bingley, R. Welch and W. J. Harrison.
To record and determine the exact significance of local terms applied in the British Isles to topographical and geological objects.	*Chairman.*—Mr. Douglas W. Freshfield. *Secretary.*—Mr. W. G. Fearnsides. Lord Avebury, Mr. C. T. Clough, Prof. E. J. Garwood, Mr. E. Heawood, Dr. A. J. Herbertson, Col. D. A. Johnston, Mr. O. T. Jones, Dr. J. S. Keltie, Mr. G. W. Lamplugh, Mr. H. J. Mackinder, Dr. E. J. Marr, Dr. H. R. Mill, Mr. H. Yule Oldham, Dr. B. N. Peach, Prof. W. W. Watts and Mr. H. B. Woodward.
To inquire into the probability of *Ankylostoma* becoming a permanent inhabitant of our coal-mines in the event of its introduction, with power to issue an interim report.	*Chairman.*—Mr. A. E. Shipley. *Secretary.*—Mr. G. P. Bidder. Mr. G. H. F. Nuttall.
To investigate the resistance of road vehicles to traction.	*Chairman.*—Sir J. I. Thornycroft. *Secretary.*—Mr. A. Mallock. Mr. T. Aitken, Mr. T. C. Aveling, Prof. T. Hudson Beare, Mr. W. W. Beaumont, Mr. J. Brown, Col. R. E. Crompton, Mr. B. J. Diplock, Prof. J. Perry, Sir D. Salomons, Mr. A. R. Sennett, Mr. E. Shrapnell Smith and Prof. W. C. Unwin.
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THE CORRESPONDING SOCIETIES OF THE BRITISH ASSOCIATION FOR 1905–1906.

Full Title and Date of Foundation.	Abbreviated Title.	Head-quarters or Name and Address of Secretary	No. of Members.	Entrance Fee.	Annual Subscription.	Title and Frequency of Issue of Publications.
Andersonian Naturalists' Society, 1885	Andersonian Nat. Soc.	204, George Street, Glasgow. R. Barbett Johnstone and T. Nisbet, M.A.	290	None	2s. 6d.	Annals, occasionally.
Anti-	Bath N. H. A. F. C. ..		70	5s.	10s.	Proceedings, annually.
Philo- ... Society, ...	Belfast N. H. Phil. Soc.		210	None	£1 1s.	Report and Proceedings, annually.
Belfast Naturalists' Field Club, 1863	Belfast Nat. F. C. ..		410	5s.	5s.	Report and Proceedings.
Berwickshire Naturalists' Club, 1831.	Berwicksh. Nat. Club ..		460	10s.	7s. 6d.	
Birmingham and Midland Institute Scientific Society, 1859	Birm. & Mid. Inst. Sci. Soc.		143	None	10s. 6d.	Observations, annually.
Birmingham Natural History and Philosophical Society, 1858	Birm. N. H. Phil. Soc.		174	None	£1 1s.	Proceedings, occasionally.
Bristol Naturalists' Society, 1862 ..	Bristol Nat. Soc. ..		162	5s.	10s. and 5s.	Proceedings, annually.
Buchan Field Club, 1887	Buchan F. C.		170	5s.	5s.	Transactions, annually.
Burton-on-Trent Natural History and Archæological Society, 1876	Burt. N. H. Arch. Soc. ..		200	None	5s.	Annual Report, Transactions, occasionally.
Canada, Royal Astronomical Society of, 1884	Roy. Astr. Soc. of Canada		150	None	2 dollars.	Transactions, annually.
Caradoc and Severn Valley Field Club, 1893	Car. & Sev. Vall. F. C. ..		186	5s.	5s.	Transactions and Record of Bare Facts, annually.
Cardiff Naturalists' Society, 1867 ..	Cardiff Nat. Soc. .		410	None	15s.	Transactions, annually.
Chester Society of Natural Science, Literature and Art, 1871	Chester Soc. Nat. Sci. ..		1086	None	5s.	Report and Proceedings, annually.
Cornwall, Royal Geological Society of, 1814	Cornw. R. Geol. Soc. ..		96	None	£1 1s.	Transactions, annually.
Croydon Natural History and Scientific Society, 1870	Croydon N. H. Sci. Soc.		200	None	10s.	Proceedings and Transactions, annually.
... and Anti-	Dorset N. H. A. F. C. .	Rev. Herbert Pentin, M.A., Milton Abbey Vicarage, Dorset.	361	10s.	10s.	Proceedings, annually.
Club, 1886 .	Dublin N. F. C. ..	J. de W. Hinch, National Library of Ireland, Dublin, and F. O. B. Ellison, B.A.	130	5s. Associates, none	5s. Associates, 2s. 6d.	*Irish Naturalist*, monthly. Report, annually.
East Kent Scientific and Natural History Society, 1857	E. Kent S. N. H. Soc.	A. Lander, The Medical Hall, Canterbury	92	None	10s.	Transactions, annually.

THE CORRESPONDING SOCIETIES OF THE BRITISH ASSOCIATION FOR 1905-1906.—*Continued.*

Full Title and Date of Foundation.	Abbreviated Title.	Head-quarters or Name and Address of Secretary.	No. of Members.	Entrance Fee.	Annual Subscription.	Title and Frequency of Issue of Publications.
Eastbourne Natural History Society, 1867	Eastbourne N H. Soc.	Gorringe	120	2s. 6d.	7s. 6d.	Transactions, biennially.
Edinburgh Geological Society, 1834	Edinb. Geol. Soc.	John	200	10s. 6d.	12s. 6d.	Transactions, annually.
Elgin and Morayshire Literary and Scientific Association, 1836	Elgin Lit. Sci. Assoc.	House,	165	None	5s.	Transactions, occasionally.
Essex Field Club, 1880	Essex F C	Epping, Essex.	301	None	15s.	*Essex Naturalist*, quarterly; *Special Memoirs*, &c., occasionally.
Glasgow, Geological Society of, 1858	Glasgow Geol. Soc.	J. Peter Macnair	350	None	10s.	Transactions, annually.
Glasgow, Natural History Society of, 1851	Glasgow N. H. Soc.	Alex. Ross, 2 Kennyhill Gardens, Dennistoun, Glasgow	297	None	7s. 6d.	Transactions and Proceedings, annually
Glasgow, Royal Philosophical Society of, 1802	Glasgow R. Phil. Soc.	Prof Peter Bennett, 207, Bath Street, Glasgow	1,000	£1 1s.	£1 1s.	Proceedings, annually.
Halifax Scientific Society, 1874	Halifax S. S.	F. Barker, 11, Hall Street, Halifax	143	None	2s. 6d.	*Halifax Naturalist*, every two months.
Hampshire Field Club and Archæo-	Hants F C.		250	None	7s. 6d.	Proceedings, annually
Natural	Haslemere Mic. N H. Soc		452	None	Minimum, 2s.	Report, annually; Science Papers, occasionally.
ory So-	Herts. N H. Soc.		160	10s.	10s.	Transactions, four times a year
Club,	Holmesdale N H. C	G. E. Frisby, 9, Fengates Road, Redhill.	99	None	10s. and 5s.	Proceedings, every two or three years.
	Hull Geol. Soc	J W Stather, F G S., 16, Louis Street, Hull	78	None	5s.	Transactions, annually.
Hull Scientific and Field Naturalists' Club, 1886	Hull Sci. F N C.	T Sheppard, F G.S., The Museum, Hull.	180	None	5s.	Transactions, annually.
Institution of Mining Engineers, 1889	Inst. Min. Eng.	Hall, New-	3,400	None	None	Transactions, monthly
and Field	Inverness Sci. Soc.	igh Street,	189	None	5s.	Transactions, occasionally.
Social In-	Stat. Soc. Ireland	M Falkiner Molesworth	100	None	£1	Journal, annually.
Leeds Geological Association, 1873	Leeds Geol. Assoc.	Sunnyside, Cross-	80	None	5s.	Transactions, biennially.
Leeds Naturalists' Club and Scientific Association, 1868	Leeds Nat. C Sci Assoc.	4, Tempest Road,	77	None	6s.	Transactions, occasionally.

THE CORRESPONDING SOCIETIES OF THE BRITISH ASSOCIATION FOR 1905–1906.—*Continued.*

Full Title and Date of Foundation.	Abbreviated Title.	Head-quarters or Name and Address of Secretary.	No. of Members.	Entrance Fee.	Annual Subscription.	Title and Frequency of Issue of Publications.
Leicester Literary and Philosophical Society, 1835	Leicester Lit. Phil. Soc.		350 Members & Associates	None	Members, £1 1s.; Associates, 10s. 6d.	Transactions, half-yearly
Liverpool Engineering Society, 1875 ..	Liverpool E. Soc. ..		550	None	£1 1s. and 10s. 6d.	Transactions and Report, annually.
Liverpool Geographical Society, 1891	Liverpool Geog. Soc. ..		660	None	Members, £1 1s.; Associates, 10s. 6d.	Transactions and Report, annually.
Liverpool Geological Society, 1859 ..	Liverpool Geol. Soc. .		70	None	£1 1s. and 10s. 6d.	Proceedings, annually.
London: City of London College Science Society	Lond. Coll. Sci. Soc. ..		80	None	5s.	Journal, monthly.
London: Quekett Microscopical Club, 1865	Quekett Club		383	None	10s.	Journal, half-yearly.
Manchester Geographical Society, 1884	Manch. Geog. Soc. ..		600	None	Members, £1 1s.; Associates, 10s. 6d.	Journal, quarterly; *Geography*, monthly.
Manchester Geological and Mining	Manch. Geol. Min. Soc.		360	None	£2 2s., £1 5s., and £1	Transactions, monthly.
Society,	Manch. Mic. Soc. .		214	5s.	6s.	Transactions and Report, annually.
Manchester Statistical Society, 1833 ..	Manch. Stat. Soc. .		207	10s. 6d.	10s. 6d.	Transactions, annually.
Marlborough College Natural History	Marlb. Coll. N. H. Soc.		280	1s. 6d.	3s. and 5s.	Report, annually.
ution of	Mid. Count. Inst. .	G. Alfred Lewis, M.A., Albert Street, Derby.	420 Membs., Associates & Students	£1 1s. None	Members £1 11s. 6d.; Associates and Students, £1	
Midland Institute of Mining, Civil and Mechanical Engineers, 1869	Mid. Inst. Eng. .. .	L. T. O'Shea, The University, Sheffield.	306	None	£1 10s.	monthly
	Norf. Norw. Nat. Soc.	W. A. Nicholson, St. Helen's Square, Norwich.	277	None	5s.	Transactions, annually.
and Mechanical Engineers, 1852	N. Eng. Inst. . ..	M. Walton Brown, Neville Hall, Newcastle-upon-Tyne.	1,350	None	£2 2s. and £1 5s.	*Transactions of the Institu-*
North Staffordshire Field Club ..	N. Staffs. F. C.	W. Wells Bladen, Stone, Staffs.	481	5s.	5s.	
	Northants. N. H. Soc.		210	None	10s.	
	Northumb. N. H. Soc. ..		480	None	£1 1s.	Transactions, annually
Nottingham Naturalists' Society, 1852	Nott. Nat. Soc. . ..		180	2s. 6d.	5s.	Report and Transactions, annually

THE CORRESPONDING SOCIETIES OF THE BRITISH ASSOCIATION FOR 1905–1906.—*Continued.*

Full Title and Date of Foundation.	Abbreviated Title.	Head-quarters or Name and Address of Secretary.	No. of Members.	Entrance Fee.	Annual Subscription.	Title and Frequency of Issue of Publications.
... Institution,	Paisley Phil. Inst. ..	J. Gardner, 3 County Place, Paisley	630	5s.	7s. 6d.	Report, annually; Meteorological Obs., occasionally
...atural Science,	Perths. Soc. N. Sci. ..	Tay Street, Perth. S. T. Ellison ..	360	2s. 6d.	5s. 6d.	Transactions and Proceedings, annually.
Rochdale Literary and Scientific Society, 1878	Rochdale Lit. Sci. Soc.	J. Reginald Ashworth, D.Sc., 105, Freehold Street, Rochdale.	253	None	6s.	Transactions, biennially.
Rochester Naturalists' Club, 1878 ..	Rochester N. C. ..	John Hepworth, Linden House, Rochester.	186	None	5s.	*Rochester Naturalist*, quarterly.
Somersetshire Archæological and Natural History Society, 1849	Som'setsh. A.N H. Soc.	The Castle, Taunton. Lt.-Col. J. R. Bramble, Rev. F. W. Weaver and C. Tite.	643	10s. 6d.	10s. 6d.	Proceedings, annually.
South African Philosophical Society,	S. African Phil. Soc. ..	G. M. Clark, South African Museum,	207	None	£1	Transactions, occasionally
...f Scientific	S.-E. Union ..	... B.A.,	43 Societies	None	Minimum 5s.	*South-Eastern Naturalist*, annually.
...hilosophical	Southport Lit. and Phil. Soc.	... Lane,	151	None	6s.	Proceedings, annually.
... East Wor... of Mining	S. Staffs. Inst. ..	... R., 3, ...	192	£1 1s. and 10s. 6d.	£1 11s. 6d. and £1 1s.	*Transactions of the Institution of Mining Engineers*, monthly.
Tyneside Geographical Society, 1887 ..	Tyneside Geog. Soc. ..	Geographical Institute, St. Mary's Place, Newcastle-upon-Tyne. Herbert Shaw, B.A., F.R.G.S.	1,000	None	10s.	Journal, annually.
Warwickshire Naturalists' and Archæologists' Field Club, 1854	Warw. N. A. F. C. ..	—	81	2s. 6d.	5s.	Proceedings, annually.
Woolhope Naturalists' Field Club, 1851	Woolhope N. F. C. ..		250	10s.	10s.	Transactions, biennially
Yorkshire Geological and Polytechnic Society, 1837	Yorks. Geol. Poly. Soc.	Rev. Wm. Lower Carter, M.A., F.G.S., Hopton, Mirfield	193	None	13s.	Proceedings, annually.
Yorkshire Naturalists' Union, 1861	Yorks. Nat. Union ..	The Museum, Hull. T. Sheppard, F.G.S.	406 and 2,700 Associates	None	10s. 6d.	Transactions, annually; *The Naturalist*, monthly.
Yorkshire Philosophical Society, 1822	Yorks. Phil. Soc. ..	Museum, York. Dr. Tempest Anderson, C. E. Elmhirst and Oxley Grabham, M.A.	400	None	£3	Report, annually.

CATALOGUE OF THE MORE IMPORTANT PAPERS, AND ESPECIALLY THOSE REFERRING TO LOCAL SCIENTIFIC INVESTIGATIONS, PUBLISHED BY THE CORRESPONDING SOCIETIES DURING THE YEAR ENDING MAY 31ST, 1905.*

Section A.—MATHEMATICAL AND PHYSICAL SCIENCE.

ALLEN, H. STANLEY. "Experiments in Radio-Activity." *Proc. Glasgow R. Phil. Soc.*, vol. xxxv., pages 82-96, 1904.

— "Notes on Physical Apparatus." *Proc. Glasgow R. Phil. Soc.*, vol. xxxv., pages 176-180, 1904.

ASHWORTH, JAMES (N. Eng. Inst. Eng.). "Observations on Water-sprayed or Damped Air in Coal-mines." *Trans. Inst. Min. Eng.*, vol. xxix., pages 11-21, 1905.

BORGSTRÖM, DR. L. H. "The Shelburne Meteorite." *Proc. R. Astr. Soc. Canada*, 1904, pages 69-94, 1905.

BROWN, M. WALTON. "Barometer, Thermometer, etc., Readings for the Year 1902." *Trans. Inst. Min. Eng.*, vol. xxv., pages 839-848, 1904.

DUKES, DR. T. ARCHIBALD. "The Parallel Roads of Glen Roy." *Trans. Croydon N. H. Sci. Soc.*, 1903-1904, pages 23-34, 1904.

FOLL, ADOLPHUS F. "The Hammer-Fennell Tachymeter-Theodolite." *Trans. Inst. Min. Eng.*, vol. xxvii., pages 373-387, 1905.

GEORGI, MAURICE (Mid. Inst. Eng.). "Notes and Considerations on Systems having Work of an Intermittent and Irregular Character to perform: Methods of Load-compensation." *Trans. Inst. Min. Eng.*, vol. xxviii., pages 89-113, 1905.

GRAY, PROF. ANDREW. "The Development of Electrical Science during the Nineteenth Century, and the Electromagnetic Theory of Light." *Proc. Glasgow R. Phil. Soc.*, vol. xxxv., pages 1-54, 1904.

HOEFER, HANS. "Underground Temperatures, especially in Coal-mines." *Trans. Inst. Min. Eng.*, vol. xxvii., pages 351-367, 1905.

LAMPLOUGH, F. E. "The Age of the Earth." *Journal Northants N. H. Soc.*, vol. xii., pages 220-227, 1904.

LATHAM, BALDWIN. "Croydon Bourne-flows." *Trans. Croydon N. H. Sci. Soc.*, 1903-1904, appendix, pages 1-44 and diagrams, etc., 1904.

MAUNDER, E. WALTER. "Magnetic Disturbances, 1882-1903, as recorded at the Royal Observatory, Greenwich, and their Association with Sun-spots." *Proc. R. Astr. Soc. Canada*, 1904, pages 95-100, 1905.

MONCK, W. H. S. "Further Considerations on Aërolites." *Proc. R. Astr. Soc. Canada*, 1904, pages 10-20, 1905.

SCOTT, DUNBAR D. "Mine-surveying Instruments," Part II. *Trans. Inst. Min. Eng.*, vol. xxviii., pages 624-684, 1904.

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Section B.—CHEMISTRY.

BEILBY, G. T. "Advances in Chemical Industry during the Nineteenth Century." *Proc. Glasgow R. Phil. Soc.*, vol. xxxv., pages 189-217, 1904.

BROWN, HORACE F. "A New Process of Chlorination for Mixed Gold and Silver Ores." *Trans. Inst. Min. Eng.*, vol. xxvii., pages 529-534, 1905.

DAWKINS, PROF. W. BOYD, and J. BARNES. "The Physical and Chemical Properties of the so-called Coal-deposit exhibited by Mr. Henry Hall, I.S.O." *Trans. Manch. Geol. Min. Soc.*, vol. xxviii., pages 539-542, 1904.

* Titles of Papers on other Subjects than Mining or Mechanical Engineering have not been reprinted.

DVORKOVITZ, DR. P. "Petroleum and its Use for Illumination, Lubricating and Fuel Purposes." *Trans. Inst. Min. Eng.*, vol. xxvii., pages 495-506, 1905.

FARMER, GEORGE (Inst. Min. Eng.). "The Problem of Gob-fires." *Trans. Inst. Min. Eng.*, vol. xxviii., pages 434-450, 1904.

HARVEY, SIDNEY. "Presidential Address." [The Wonders of Radium.] *Trans. E. Kent S. N. H. Soc.*, vol. iv., pages 1-3, 1905.

HENDERSON, PROF. G. G. "Some Developments in Chemical Theory during the Nineteenth Century." *Proc. Glasgow R. Phil. Soc.*, vol. xxxv., pages 97-119, 1904.

KERSHAW, JOHN B. C. "Fuel-economy from the Chemical Point of View." *Trans. Liverpool Eng. Soc.*, vol. xxv., pages 27-48, 1904.

LISHMAN, DR. G. P. "The Analytical Valuation of Gas-coals." *Trans. Inst. Min. Eng.*, vol. xxvii., pages 516-526, 1905.

— (N. Eng. Inst.). "Notes on Safety-lamp Oils." *Trans. Inst. Min. Eng.*, vol. xxviii., pages 338-340, 1905.

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Section C.—GEOLOGY.

ALLANSON-WINN, R. G. "The Sea's Encroachment on the East Coast." *The Naturalist* for 1904, pages 305-308, 1904.

BALDWIN, WALTER. "A Carboniferous Air-breather from Sparth Bottoms, Rochdale." *Trans. Manch. Geol. Min. Soc.*, vol. xxviii., pages 523-527, 1904.

— (Manch. Geol. Min. Soc.). "Sparth Bottoms Quarry, Rochdale." *Trans. Inst. Min. Eng.*, vol. xxviii., pages 301-302, 1905.

BARKE, F. "Further Notes on the Occurrence of Glacial Drift in the Potteries." *Trans. N. Staffs. F. C.*, vol. xxxviii., pages 113-117, 1904.

BELL, ROBERT. "Notes on the Discovery of Dopplerite in Sluggan Bog." *Proc. Belfast Nat. F. C.*, vol. v., pages 216-217, 1905.

BLASHILL, THOS. "Changes in Spurn Point and their Bearing on the Site of Ravenscar." *The Naturalist* for 1904, pages 264-268, 1904.

BOLTON, HERBERT. "The Palæontology of the Lancashire Coal-measures." Parts II. and III. *Trans. Manch. Geol. Min. Soc.*, vol. xxviii., pages 578-650, 668-689, 1904.

BOOTH, WM. H. "Artesian Wells." *Journ. City of London Coll. Sci. Soc.*, vol. x. pages 43-49, 1905.

BROWNE, A. J. JUKES. "The Geology of the Country round Chard." *Proc. Somersetshire A. N. H. Soc.*, vol. ix., pages 12-22, 1904.

BUTTERFIELD, A. E. "Notes on the Growth of Spurn." *The Naturalist* for 1904, pages 325-328, 1904.

COLENUTT, G. W. "Freshwater Bay, Isle of Wight." *Proc. Hants F. C.*, vol. iv., pages 82-92, 1905.

COLLINS, J. H. "Anniversary Address." [The Geology of the District.] *Trans. Cornwall R. Geol. Soc.*, vol. xiii., pages 9-20, 1905.

COLLYER, H. C. "Jade or Nephrite." *Trans. Croydon N. H. Sci. Soc.*, 1903-1904, pages 34-40, 1904.

COPE, T. H. "Types of Rock-flow in the Ceiriog Valley, and their Analogies with River-structure." [Presidential Address.] *Proc. Liverpool Geol. Soc.*, vol. ix., pages 303-331, 1904.

CULPIN, H., and G. GRACE. "Preliminary Note on Upper Coal-measures in Yorkshire." *Proc. Yorks. Geol. Poly. Soc.*, vol. xv., page 330, 1905.

— — "An Exposure of Upper Coal-measures near Conisborough." *The Naturalist* for 1905, page 40, 1905.

Davison, Dr. C. "Yorkshire Earthquakes." *The Naturalist* for 1905, pages 26-28, 1905.

Dawkins, Prof. W. Boyd (Manch. Geol. Min. Soc.). "A Section of the Glacial Deposits met with in the Construction of the New Docks at Salford." *Trans. Inst. Min. Eng.*, vol. xxviii., pages 372-373, 1905.

— "The Permian and Carboniferous Rocks in a Section in High Street, Chorlton-on-Medlock, Manchester." *Trans. Inst. Min. Eng.*, vol. xxviii., pages 375-377, 1905.

Dibley, G. E. "The Fauna and Lithological Features of the Chalk in the Rochester District." *Rochester Naturalist*, vol. iii., pages 297-304, 1905.

Dickson, E. "Notes on some of the Small Glaciers and Glacial Deposits near the Summit of the Furka Pass, and a Comparison with Similar Deposits in the English Lake District." *Proc. Liverpool Geol. Soc.*, vol. ix., pages 388-400, 1904.

Dron, R. W. (Mining Inst. Scot.). "The Occurrence of Calcareous Coal in a Lanarkshire Coal-field." *Trans. Inst. Min. Eng.*, vol. xxvii., pages 92-94, 1905.

Du Toit, Alex. L. "The Forming of the Drakensberg." *Trans. S. African Phil. Soc.*, vol. xvi., pages 53-71, 1905.

Dwerryhouse, A. R. "The Underground Waters of North-west Yorkshire." *Proc. Yorks. Geol. Poly. Soc.*, vol. xv., pages 248-292, 1905.

Fox, Howard. "Further Notes on the Devonian Rocks and Fossils in the Parish of St. Minver." *Trans. Cornwall R. Geol. Soc.*, vol. xiii., pages 33-87, 1905.

Gerrard, John. "Notes on Fossils found above the Bradford Four-feet Coal at Bradford Colliery, Manchester." *Trans. Manch. Geol. Min. Soc.*, vol. xxviii., pages 555-562, 1904.

Gibson, Walcot. "Sections of Bore-holes and Wells in the County of Stafford." *Trans. N. Staffs. F. C.*, vol. xxxviii., pages 122-149, 1904.

Greener, G. A. "The Coal-fields of the Faröe Islands." *Trans. Inst. Min. Eng.*, vol. xxvii., pages 331-340, 1905.

Halse, Edward. "Some Silver-bearing Veins of Mexico" (concluded). *Trans. Inst. Min. Eng.*, vol. xxvii., pages 169-189, 1905.

Harmer, F. W. "The Pleistocene Deposits of East Anglia." *Proc. Yorks. Geol. Poly. Soc.*, vol. xv., pages 315-329, 1905.

Hobson, B. "A Glacial Boulder from Red Bank, Hanging Ditch, Manchester." *Trans. Manch. Geol. Min. Soc.*, vol. xxviii., pages 549-551, 1904.

Hogg, A. J. "The Gravels of South Norwood Hill." *Trans. Croydon N. H. Sci. Soc.*, 1903-1904, pages 18-19, 1904.

Jackson, Douglas (Mining Inst. Scot.). "Natural Coke in Douglas Colliery, Lanarkshire." *Trans. Inst. Min. Eng.*, vol. xxvii., pages 251-252, 1905.

Jowett, A., and H. B. Muff. "The Glaciation of the Bradford and Keighley District." *Proc. Yorks. Geol. Poly. Soc.*, vol. xv., pages 193-247, 1905.

Kendall, Percy F., and H. Howarth. "The Yorkshire Boulder Committee and its Eighteenth Year's Work, 1903-1904." *The Naturalist* for 1905, pages 78-80, 1905.

Kerr, Walter. "Rocks and Minerals of the Crieff District." *Trans. Perths. Soc. Nat. Sci.*, vol. iv., pages 1-21. 1904.

— "The Amœboid Agates of Monzie, near Crieff." *Trans. Perths. Soc. Nat. Sci.*, vol. iv., pages 21-24, 1904.

— "Preliminary List of Minerals occurring in Perthshire." *Trans. Perths. Soc. Nat. Sci.*, vol. iv., pages 25-27, 1904.

LOMAS, J. "The Coasts of Lancashire and Cheshire, their Forms and Origin." *Proc. Liverpool Geol. Soc.*, vol. ix., pages 332-339, 1904.

MACNAIR, PETER. "On Pseudogaylussite dredged from the Clyde at Cardross, and other recent Additions to the Mineral Collection in the Kelvingrove Museum." *Proc. Glasgow R. Phil. Soc.*, vol. xxv., pages 250-262, 1904.

MONCKTON, G. F. "Cinnabar-bearing Rocks of British Columbia." *Trans. Inst. Min. Eng.*, vol. xxvii., pages 463-469, 1905.

MORGAN, DR. C. LLOYD, and PROF. S. H. REYNOLDS. "The Field-relations of the Carboniferous Volcanic Rocks of Somerset." *Proc. Bristol Nat. Soc.*, vol. x., pages 188-212, 1904.

ORIEL, REV. B. "The Avon and its Gravels." *Proc. Bristol Nat. Soc.*, vol. x., pages 228-240, 1904.

PRESTON, HENRY. "The Red Rocks underlying Lincolnshire." *The Naturalist* for 1904, pages 313-315, 1904.

READE, T. MELLARD. "On some Borings at Altcar made by the Lancashire and Yorkshire Railway Company." *Proc. Liverpool Geol. Soc.*, vol. ix., pages 359-369, 1904.

READE, T. MELLARD, and P. HOLLAND. "Sand and Sediments." Part I. "Recent Fluviatile Deposits." *Proc. Liverpool Geol. Soc.*, vol. ix., pages 370-387, 1904.

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III.—REGULATIONS OF THE VIENNA MINING DEPARTMENT RESPECTING THE PRECAUTIONS THAT ARE TO BE OBSERVED IN FIERY MINES, IN CASE OF AN EXPLOSION OF GAS OR COAL-DUST, OR OF A FIRE IN THE PIT OR IN THE SHAFT, FOR THE SECURITY OF LIFE AND PROPERTY.*

I.—Before the Explosion or Fire.

In order to secure the success of the measures which must be taken immediately after an explosion of gas or coal-dust, or of a fire in a pit or in a shaft, through which catastrophe the men engaged in the whole pit or in large districts thereof, as also the structure of the mine itself, may be endangered, all those mines which are officially considered to belong to the group of fiery mines must prepare in advance in all cases the following precautionary provisions:—

1.—In every mine, a suitable building on the surface, as near as possible to the travelling shaft, or shafts, must be arranged as a rescue-station, in which the appliances enumerated in clauses 2 and 3 must be kept at all times ready, in a condition suitable for immediate use. Two or more neighbouring mines can, with the authorization of the Department of Mines, erect a joint rescue-station, which must be equally accessible to both the associated pits, but must be, as regards management, subject to the manager of that pit to which it is nearest.

2.—In every rescue-station, breathing-appliances must be provided, admitting of safe use for a period of at least an hour, and allowing the greatest possible freedom of motion to those employing them. The Department of Mines shall determine what appliances may be employed for this purpose.† The number of breathing-appliances of a rescue-station, that are to be kept constantly in a condition suitable for immediate use, or in case they should have been employed for their proper purpose, or for the purposes of practice, shall immediately afterwards be put into such condition, shall be calculated as follows:—If the rescue-station is intended for one mine only, 2 per cent. of the maximum number of men on each shift inclusive of overmen and shot-firers, but in no case to be less than 10. If the rescue-station is intended for several mines, the number of breathing-appliances shall be calculated upon the maximum number of men per shift in that mine which employs the largest number. Furthermore, for the purposes mentioned in part II. B., last paragraph but one, as also for the purpose of any rapid but brief act of rescue, there shall be at the onset of each hanging-on level at least two breathing-appliances enclosed in a portable box, together with two electric lamps; in case the hanging-on level is changed, these are to be taken with them by the onsetters, should there not be the above number of breathing-appliances and electric lamps constantly kept in the immediate neighbourhood of the shaft, at the level in question. The onsetters have to assure themselves, before the commencement of each shift, that the breathing-appliances and electric lamps are in good condition.

* Verordnung der k.k. Berghauptmannschaft Wien betreffend die Vorkehrungen, welche bei Schlagwettergruben für den Fall des Eintrittes einer Schlagwetter- oder Kohlenstaubexplosion, eines Gruben- oder eines Schachtbrandes zur Sicherung von Personen und Eigentum zu treffen sind. 11 Oktober 1905.—Translated by Prof. Henry Louis, M.A.

† Part IV.

3.—In the rescue-station, there shall further be a number of electric pit-lamps, in a condition fit for immediate use, equal in number to the breathing-appliances, as also an equal number of smoke-proof goggles, as far as these may be rendered necessary by the system of breathing-appliance employed, as, also, a suitable quantity of tarred linen or sailcloth (brattice-cloth) for the rapid formation of temporary air-stoppings.

4.—The manager shall nominate an employee or overman of the higher class, whose name shall be entered in the colliery-book, who is to be held responsible for keeping all the appliances of the rescue-station in a proper condition. He shall keep an inventory of all the appliances kept in the station, as also reports upon the testing, from time to time, of such appliances (testing the pressure of the oxygen-bottles, electric lamps, etc.). This inventory shall be kept in the rescue-station.

5.—At each pit, a number of workmen, exceeding at least by two the number of breathing-appliances prescribed in paragraph 2, shall be trained as a rescue-party, in the use of these appliances, lamps, etc. In the selection of these men, as far as possible, care shall be taken that they are suitably distributed throughout the various shifts. Care must be taken to provide, in due course, for the replacement of any men who may be withdrawn from the number of the rescue-party. It is recommended that the rescue-parties of neighbouring mines shall be united to form a rescue-corps. In this case, care should be taken that easy communication between the separate mines is provided, in order that an alarm may be promptly transmitted. The men of the rescue-party, thus united into a corps, must make themselves acquainted with the main travelling-roads of the neighbouring mines, in which they may be called upon to serve for rescue-purposes. The formation of such a rescue-corps is to be notified to the inspector of mines for the district, indicating upon what basis this has been carried out. The practices in irrespirable gases necessary for training the rescue-parties shall be performed by the entire party at least every other month, and each member of the party shall employ the apparatus assigned to him as long as he is capable of doing so. Practices with breathing-appliances in the mine, even if not in places fouled with gas, are to be counted as equivalent to the above, provided that the members of the rescue-party have previously been practised in smoke-chambers in the use of these appliances. Before they are enrolled, the members of the rescue-party must be examined by a medical man and found physically fit. Those who, in practices in the smoke-chamber, cannot breathe for at least ¾ hour without intermission whilst using the breathing-apparatus during the course of the last five practices, must be dismissed from the rescue-party. The names and full addresses of the members of the rescue-party shall be entered by the responsible person designated under No. 4 clause in a list, one copy of which shall lie at the rescue-station, and another in the lamp-room. Any changes or vacancies shall immediately be made good. The reports of the practices carried out by the members of the rescue-party shall be entered in a record-book in accordance with form, see part III.

6.—The manager shall, as far as practicable, make certain members of the party acquainted in advance with the part that they will have to take in carrying out special measures in case of a catastrophe (see part II. of these regulations), so that they may know in advance exactly what task will fall to their share should the occasion arise.

7.—The manager shall issue an order to the effect that, in case of an accident involving danger, a state of "permanent service" shall be declared; that is to say, that all the officials and superintendents under the orders

of the manager shall immediately take up their respective posts without further notification, so that such men, on leave or absent through other causes, shall immediately be ordered to return to their posts, and that none shall be permitted to leave such post without permission of the manager, until the state of "permanent service" shall have been determined.

II.—After the Explosion or Fire.

The success of the action to be taken immediately after the occurrence of a dangerous accident of the kind indicated under part I., can be promoted not only by the preparation of the necessary provisions, etc., as explained under part I., but also by the manager having previous knowledge of the applicability and extent of such measures, which, although in each special case they must depend entirely upon the nature and dimensions of the catastrophe and upon local conditions, can also possibly be foreseen to some extent, as in this way only is it possible to prevent a mistake that might be fraught with injurious consequences.

With this purpose, the following suggestions may be indicated, of which those under heading A refer to explosions of gas or coal-dust and to fires inside the pit-workings, and those under B to fires in the shafts.

A.—*Measures to be taken in the Case of an Explosion of Gas or Coal-dust, or of a Pit-fire.*—The manager must first of all investigate whether the fan is in order, and whether any shaft-coverings that may exist on the mine are in their proper places; any deficiencies must at once be repaired by experienced hands. An increase in the speed of the ventilator will only be admissible exceptionally, as the safe running of the fan is far more important in these cases than an increase of the volume of air circulating, and this increase of volume very probably will not even attain any important proportions. If the explosion has brought in its train a pit-fire, any increase of the velocity of the air-current would even be injurious, and might under circumstances when men are compelled to retire before after-damp and smoke, entail serious consequences. During the whole course of the rescue-operations the fan must continually be watched by an experienced man, under whose supervision the regulation of its velocity, as determined from time to time by the manager, shall be carried out. Medical aid must be requisitioned in sufficient quantity; furthermore, the remedies, bandages, etc., as well as men practised in first aid, must be placed at the disposal of the doctors present. The rescue-party must receive an alarm-call, and must be supplied in the rescue-station with the necessary appliances; or, in case of need, the alarm must be communicated to the entire rescue-corps of the neighbouring mines; and, further, in case of need, the neighbouring mines must be asked to give assistance by means of rescue-parties and appliances. A list must be made of the men riding in or out of the pit immediately after the accident, and during the course of the rescue-operations, by an official posted at the pit-mouth, in order the more rapidly to determine whether any may be missing. Overmen riding out with their gangs must present themselves to the manager and report to him, unless special instructions in this respect have been given to them. The necessary precautions must be taken to prevent a crowd of inquisitive spectators from invading the pit-top. The local inspector of mines, the Mines Department, and the nearest police-station are to be informed by telegraph or telephone. The execution of the actual operations of rescue, or of restoration of the pit, and their further conduct, depends entirely upon the nature and

extent of the accident that has originated the danger, as also of the locality thereof, so far as an opinion can be formed on this point from the observations and reports received. In general, it will have to be considered whether indications are present, that lead to the belief that the explosion has originated a pit-fire; and this may be known, at least when the accident has taken place in the day-time, from the fact that smoke, becoming continually darker, is seen issuing from the fan-chimney. If there be no evidence that a fire has broken out, the rescue-operations can be carried on, if due precautions be taken, without danger, by following the course of the air-current traversing the field of the explosion, from the intake-airway, and by successively replacing the stoppings, brattices, etc., that have been destroyed by the explosion, so as to restore the ventilating current, thus enabling the men to enter the area of the accident in a current of fresh air. In order to execute this with the greatest speed possible, the rescue-party may be divided into two portions, one of which shall advance as rapidly as possible, without taking any heed of the restoration of the normal ventilating current, as far as may be practicable with the available breathing-appliances, so as to bring men, who have been injured or rendered insensible, as rapidly as possible into fresh air, whilst the other party restores the ventilating current as quickly as possible. In many of these cases, it may be recommended to increase the ventilating current in the endangered portions of the pit, at the expense of the other circuits, provided that there is a certainty that those men who may have remained in such portions of the pit as are ventilated by the latter circuits of air, are not thereby running any risk. If, on the other hand, there is good ground for supposing that a pit-fire has been already originated, the process described in the previous paragraph is not to be recommended; the attempt should rather be made to advance as rapidly as possible towards the working-faces by the aid of volunteers, in order to get out the men who may have remained behind. If, however, on account of the known position of the fire, as, for example, in the neighbourhood of a goaf, probably containing dangerous gases, there is reason to fear that fresh explosions may arise, or if such have actually arisen, and especially if the violence and extent of the first explosion has led to the conviction that no living persons can be left within the area of the explosion, rescue-operations should be abandoned, so as not to endanger the rescue-party itself without sufficient cause. In that case, suitable precautions should at once be taken to stifle the pit-fire.

Assuming the special case of an apparently serious explosion about which no reliable information has reached the surface, so that there are no indications for the conduct of the rescue-operations except the occurrence itself, the manager shall first see to the execution of the above regulations at the surface; he shall then go to the winding-shaft, and there investigate whether the hoisting arrangements are in working order, and whether the shaft is free from after-damp, for which object the cage at bank, and, in case of need, the other one also, shall be equipped with burning lights and slowly moved upwards and downwards for the purpose of investigation. He shall furthermore investigate whether the guides, etc., are in order.

He shall then decide upon sending down a rescue-party under the leadership of an official or overman, and shall see that they are equipped with breathing-appliances, electric lamps, and a few safety-lamps (to act as gas-indicators); and, according to the condition of affairs, the rescue-party shall either at once employ the breathing-appliances or only take them down ready for immediate use in case of necessity. In general, as long as the ventilating fans are working, even in the case of an extensive explosion, the after-damp that reaches

the downcast-shaft owing to the reversal of the ventilation will soon be dissipated, so that there is no serious danger for those going down immediately after the explosion.

The task of the first rescue-party that descends embraces chiefly the following points:—

(*a*) To notice whether short circuits have not taken place between the upcast and the downcast-shafts, which must be immediately repaired, if this can be done without serious loss of time; otherwise, information shall be conveyed to the manager, who shall then cause suitable operations to be carried out.

(*b*) To maintain a system of signals at the principal levels, by means of onsetters or other suitable persons.

(*c*) To bring to bank at once any persons who may be found unconscious or injured.

(*d*) To communicate with the men who may be in those portions of the pit not affected by the accident, and to cause them to leave the mine.

(*e*) After being strengthened by additional rescue-parties, which will meanwhile be sent down by the manager, and suitably equipped to advance with an ingoing air-current towards the site of the catastrophe, to investigate the same and to report upon it to the manager.

The manager shall meanwhile take care that materials required for rescue and salving operations in the pit, such as planks, brattice-cloth, nails, laths, reserve-doors, etc., shall be sent down in suitable quantity as may be required.

He shall organize the successive rescue-parties, which, equipped with breathing-appliances and electric lamps, shall strengthen the original party.

He shall receive reports from the overmen who are coming to bank with their workmen from portions of the pit not affected by the explosion, and shall take care that suitable persons acquainted with the district shall be placed at the crossings of the travelling roads to show the way, wherever this has not already been done by the above-mentioned overmen, as also that a considerable number of electric and other safety-lamps shall be sent into the pit and suitably distributed, in order that the shaft-landings and the roads may be lighted, along which the men may have to retreat to the shaft.

This having been done, he can himself descend into the pit, if he has not previously found this necessary, in order to take personal charge of the rescue and salving operations. Before doing this, however, it is compulsory upon him to leave a representative at the pit-mouth, who shall take over his duties above-described.

B.—*Measures to be taken in the Case of a Shaft-fire.*—In the case of a fire arising in the shaft from any cause whatever, the precautions mentioned under part II. A., respecting medical assistance, organization of the rescue-parties, informing the neighbouring mines in order to get assistance, control of the men riding in and out of the pit, the exclusion of inquisitive spectators from the pit-top, and giving information to the authorities, shall be carried out. If the fire has originated in an upcast-shaft, care should further be taken that the entire working staff shall be withdrawn from the pit as rapidly as possible through the downcast-shaft, after which the necessary steps shall be taken for extinguishing the fire. Should such a fire break out in the downcast-shaft, causing smoke to be distributed with the intake-air throughout the whole pit, and access to the pit be rendered practically impossible even with the employment of breathing-appliances, it only remains to convert the shaft as rapidly as possible into an upcast and to reverse the entire ventilation of the pit. This is done by stopping

the fan, and the column of air in the shaft, heated up by the fire, rapidly converts this into an upcast. This again may be increased by applying a suction-fan to the shaft in question, or by connecting it with a chimney-flue, etc. In such a case the men shall be at once rapidly withdrawn from the pit, if a second downcast-shaft is available, connecting with the pit, either belonging to the same or to a neighbouring pit; but they shall only be removed through the upcast-shaft, if there is no reason to fear that this may be reached by the current of smoke. If neither of these measures is practicable, the men shall be brought into a portion of the pit (underground rescue-station) which lies outside of the air-current, or which, by the closure of air-doors or by bratticing, can be withdrawn from the course of the air-current. Downcast-shafts, which are liable to any danger of fire, shall be supplied once and for all, at all levels, with doors, which are to stand open as a general rule; but these doors, in case of a fire in the shaft, render it possible to isolate the shaft in question from the remainder of the pit by closing them, when ventilation in the mine can again be restored by employing some other intact downcast-shaft if such an one is available. The hangers-on are to be instructed in the isolation of a burning shaft by means of the doors in question. In no case shall an attempt be made to quench the fire in a downcast-shaft by the introduction of water, before the whole of the men employed shall have left the pit.

III.—Record-book of Practices.

No.
Date of practice.
Names and employments of persons engaged in the practice.
Locality of the practice.
Occupation of the members of the rescue-party during practice.
Breathing-appliances: number.
Do. system.
Electric lamps: number.
Do. system.
Period of breathing, without intermission, minutes.
Consumption of oxygen of each individual apparatus: total litres.
Do. do. litres per minute.
Cause of termination of the practice; length of road traversed; defects or good qualities of the appliances and electric lamps; bodily condition of the men taking part during and after the practice, etc.
Name of the overman in charge of the practice.

IV.—Rescue-appliances.

Description of breathing-appliances authorized by the regulations.

1.—*Walcher-Gärtner Pneumatophore.*—This consists of a breathing-bag made of airtight material, with a capacity of at least 610 cubic inches (10 litres), fitted internally with cushions of loofah, or some other suitable material which shall give the largest possible surface for absorption. Furthermore, the bag contains an appliance containing caustic lye, consisting of a glass bottle of 26 cubic inches (425 cubic centimetres) contents, containing a 25 per cent. solution of soda, which is secured in a cylinder of perforated sheet-metal, with a screw pressing upon the glass bottle; furthermore, an oxygen-reservoir consisting of a seamless-steel bottle tested to a pressure of 250 atmospheres, with a capacity of at least 37 cubic inches (0·6 litre), filled under a pressure of 100 atmospheres, so that by means of a valve, actuated by an external hand-wheel, successive quantities of oxygen, as required from time to time, can be admitted into the breathing-bag. A breathing-tube fitted with a mouth-

piece leading from the breathing-bag conveys the current of oxygen, whilst the carbon dioxide is removed by the solution of caustic soda flowing out of the shattered glass bottle in the interior of the bag. A nose-clip prevents the entrance of irrespirable gases through the nose.

A modification of this apparatus introduced by Dr. Chimani in Ostrau, Moravia, fitted with two bottles, has two oxygen-bottles secured by a belt round the body, communication with the breathing-bag being maintained by means of copper tubes. The additional space thus obtained inside the bag, by the removal of the oxygen-bottle, allows of the introduction of a second bottle of soda-lye.

The above-described apparatus can also be fitted with reducing-valves.

2.—*Shamrock Type of Pneumatophore.*—This is a modification of the Walcher apparatus in which, instead of one oxygen-bottle, two of 37 cubic inches (0·6 litre) capacity filled at 100 atmospheres pressure are employed and carried upon the back in a bag. From this, the oxygen finds its way through a flexible pipe by means of a valve, which lifts when required. Soda-lye is poured directly into the bag before use. In addition, 67 cubic inches (1,100 cubic centimetres) of lye are carried in a knapsack.

This apparatus can also be fitted with reducing-valves.

3.—*Mayer-Pilář Breathing-apparatus.*—In this apparatus, the breathing-bag is made of two-ply indiarubber material; it is divided in the middle, so that it can be laid upon both shoulders. Above this division, a smoke-mask is placed, and fitted airtight against the face of the wearer by means of an indiarubber ring and an indiarubber disc. The mask is fitted with a plate of glass protected against damage, and with an appliance for wiping the same, which can be worked from the outside. The collar-shaped breathing-bag rests upon the shoulders, and communication between it and the mask is obtained by means of two metal pipes fitted with small valves. The oxygen-reservoir is a steel bottle or bomb of at least 61 cubic inches (1 litre) capacity, filled at a pressure of 100 atmospheres. It is carried by means of a strap or belt on the side or back, and is connected with the breathing-bag by a flexible pipe. For the absorption of the expired carbon dioxide and moisture, solid absorbents (caustic potash, caustic soda or soda-lime) are employed, preserved in glass cylinders closed airtight, and they are transferred to the bag immediately before the apparatus is used.

The above apparatus can also be fitted with reducing-valves.

4.—*Giersberg Rescue-apparatus, 1901 Type.*—This appliance consists of a frame carried upon the back, to which are attached two oxygen-bottles, each of 64 cubic inches (1·05 litre) capacity, filled at a pressure of 125 atmospheres; and an absorbent drum filled with soda-lime, or with a U-shaped metal box filled with sticks of soda-lime and small perforated metal boxes containing granulated kieselguhr, through which the products of respiration flow and are thereby purified; and afterwards, the same are, together with the fresh oxygen streaming from the reducing-valve (with a pressure-gauge), automatically conveyed to the wearer. A mask, provided with a small breathing-bag, secured airtight to the face by means of an expanded ring of indiarubber tube, is connected by means of metallic pipes with that portion of the apparatus which is carried on the back.

The use of this apparatus is also admissible without the mask, but with the mouthpiece and nose-clip.

5.—*Draeger Apparatus.*—This consists of a carrying frame, with shoulder-straps, reducing-valve, circulating appliances, surface-cooler, and

connecting pipes; of cartridges of potash, which are to be introduced into the apparatus, carried upon the frame; of oxygen-bottles, either single or double, which are also secured to the above frame; and of a breathing-appliance consisting either of a smoke-helmet with a breathing-bag, or of a breathing-bag for the mouth with a nose-clip. The carrying frame may be employed for one or two potash cartridges, also for one or two oxygen-bottles, and therefore for a longer or shorter period of use. The circulating appliance resembles in principle that of the Giersberg apparatus, and is distinguished from the latter principally by the employment of ready-made cartridges of potash, to be placed upon the apparatus, which are fitted at both ends with a clip, closed before use with a screw-plug. The oxygen-bottles are screwed to the reducing-valve, which is also supplied with a pressure-gauge; and to use the apparatus it is only necessary to open the valve of one of the two oxygen-bottles, which have a capacity of 67 cubic inches (1·1 litres), and are filled at a pressure of 110 atmospheres. The communication with the smoke-helmet or the breathing-bag is brought about by means of a flexible tube, the ends of which are fitted with readily distinguishable couplings, so as to avoid any accidental interchange. The smoke-helmet is provided with an indiarubber-tube fitting tight against the face, a small breathing-bag and a leather protection. In case the breathing-bag carried on the breast is to be employed, the fresh oxygen-current flows directly into the mouth, and the expired air is withdrawn from the middle portion. The mouthpiece is fitted with a saliva-trap and an escape-valve. Furthermore, a surface-cooler is provided, in which the air leaving the cartridge flows through a cylindrical hollow vessel with double walls, and is thereby cooled before it is again breathed.

6.—*Pneumatogen Apparatus.*—This apparatus consists of a carrying appliance containing three cartridges, each of which contains 8·8 ounces (250 grammes) of potash-soda peroxide; of a breathing-bag shaped like a coat, or else carried in a basket on the back, weighing 7 to 9 pounds (3 to 4 kilogrammes). The cartridges consist of metal cases with central apertures, which are closed before use by means of thin lead discs soldered on. The granulated potash-soda peroxide is placed inside the cartridge; above this preparation is a distributing filter made of asbestos-sheets with alternating holes, and corrugated wire-gauze. By inserting the connecting pieces, in which the flexible pipes connected with the mouthpiece terminate, into the cartridge, the lead discs are perforated, and air-tight communication is simultaneously effected with the cartridges.

The two outer cartridges serve for breathing during the period of work, whilst the third or middle cartridge is to be employed for retreating. Care should be taken, in retreating, that this cartridge should not be brought into use until the two outer ones are almost exhausted. It is imperative, before using the apparatus, that it shall first be filled with about 610 to 730 cubic inches (10 to 12 litres) of oxygen, which should either be taken from an oxygen-bottle, or it can be produced by a rapid generator containing a tabloid (1·7 ounces or 50 grammes) of potash-soda peroxide and 7 cubic inches (120 cubic centimetres) of water; in either case, a filling tube must be provided for every two pneumatogens.

Only such cartridges may be employed as bear a proof-mark from the factory, guaranteeing the proper composition and character of the preparation. After the apparatus has been employed, all cartridges that have been opened, whether they may have been wholly or only partly used, must be unconditionally replaced by new ones.

INDEX TO VOL. XXX.

EXPLANATIONS.

The — at the beginning of a line denotes the repetition of a word; and in the case of Names, it includes both the Christian Name and the Surname; or, in the case of the name of any Firm, Association or Institution, the full name of such Firm, etc.

Discussions are printed in *italics*.

The following contractions are used :—

M.C.—The Midland Counties Institution of Engineers.
M.G.—Manchester Geological and Mining Society.
M.I.—Midland Institute of Mining, Civil and Mechanical Engineers.
N.E.—The North of England Institute of Mining and Mechanical Engineers.
N.S.—The North Staffordshire Institute of Mining and Mechanical Engineers.
S.I.—The Mining Institute of Scotland.
S.S.—The South Staffordshire and Warwickshire Institute of Mining Engineers.

A.

B.

C.

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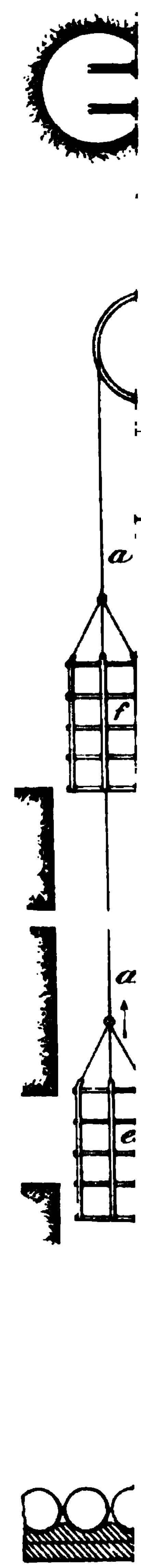
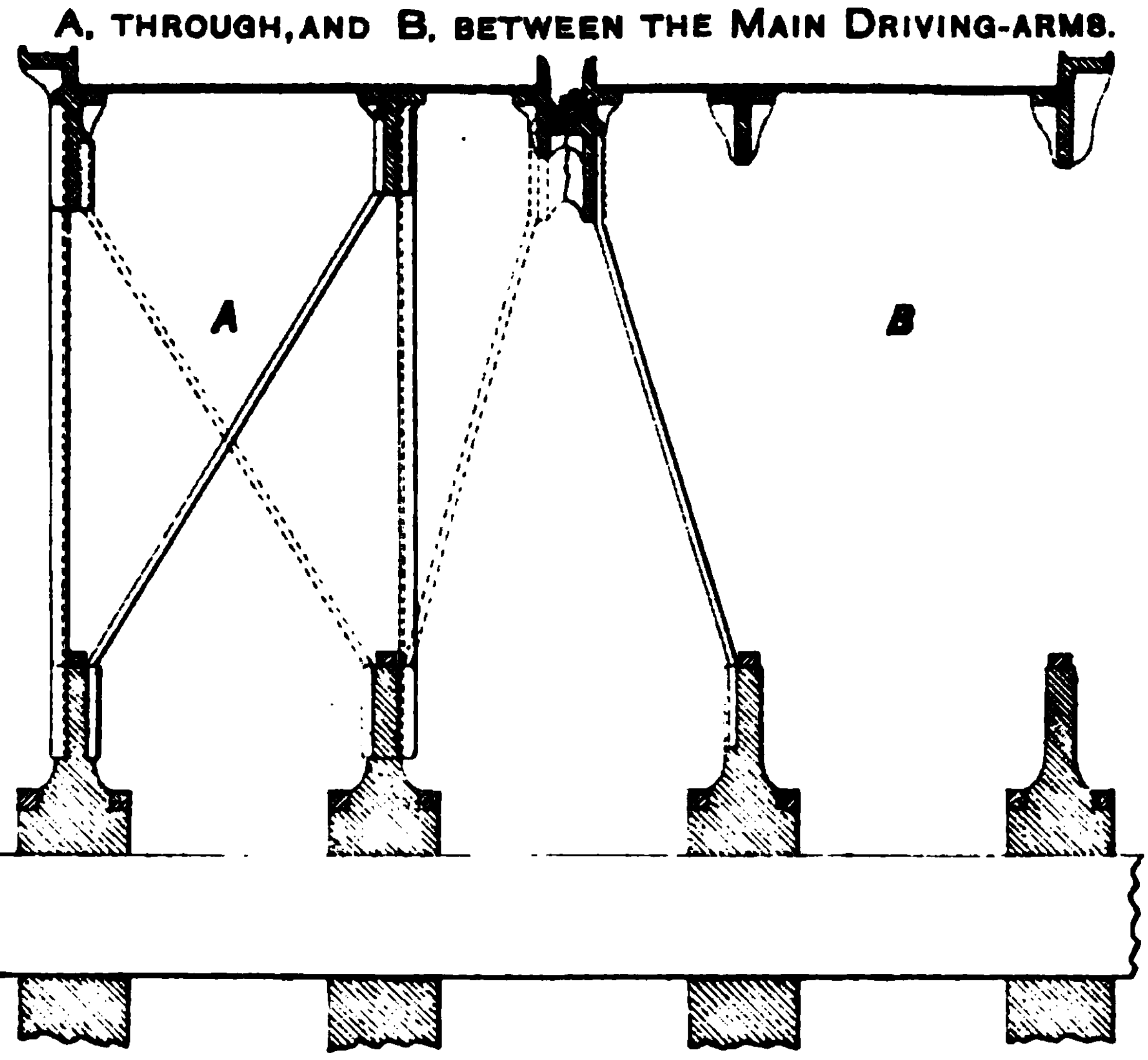
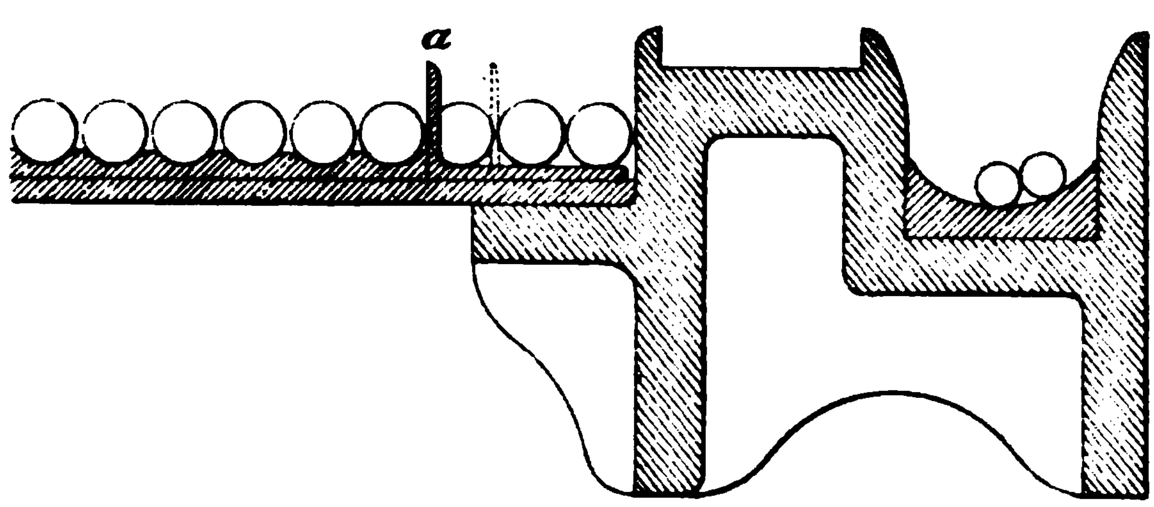


FIG. 5.—CROSS-SECTIONS OF WINDING-DRUM:
A, THROUGH, AND B, BETWEEN THE MAIN DRIVING-ARMS.



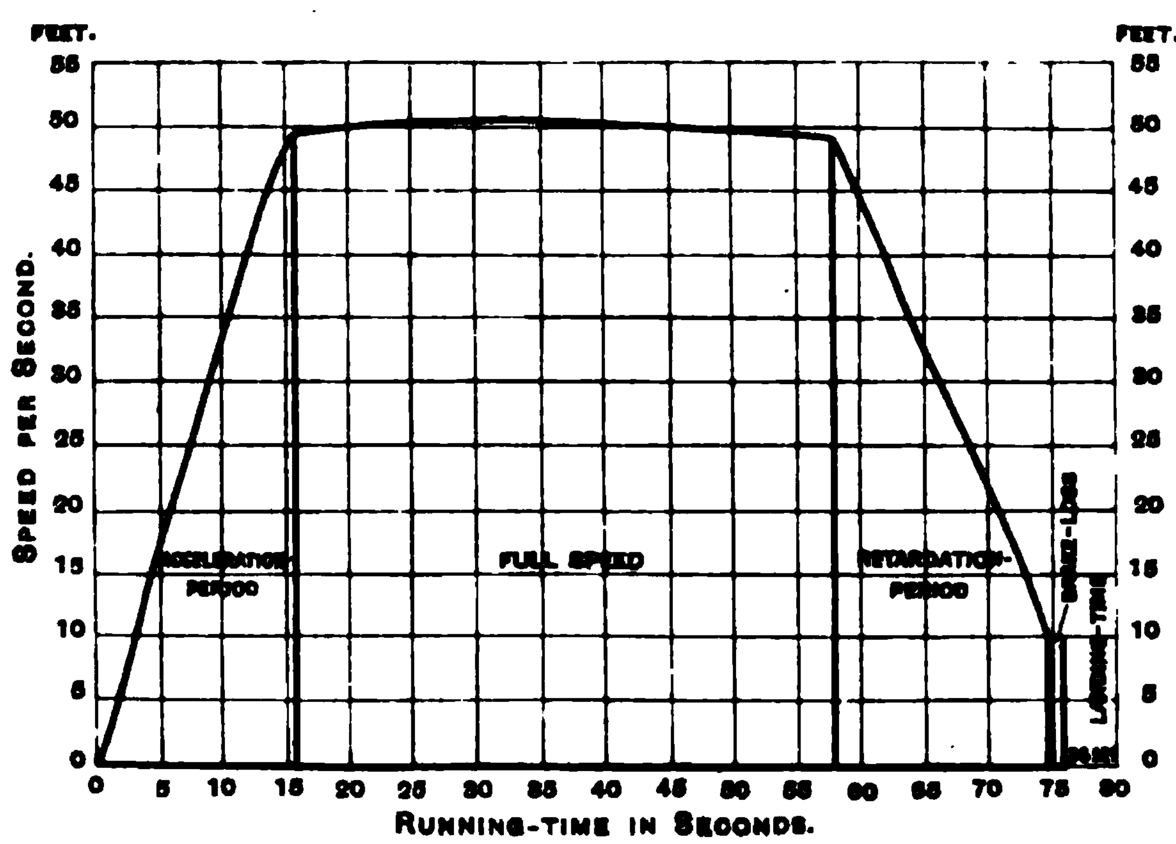
Scale, 6 Feet to 1 Inch.

FIG. 6.—CROSS-SECTION OF GROOVE
FOR BALANCE-ROPE.



Scale, 1 Foot to 1 Inch.

FIG. 9.



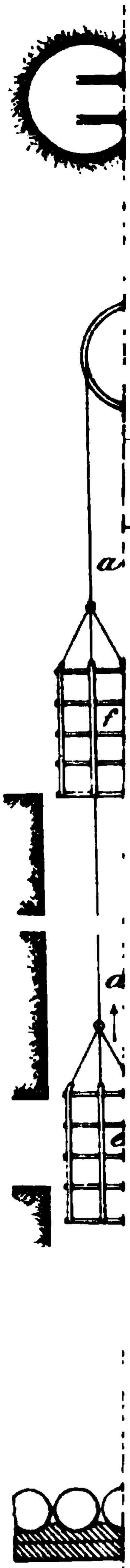
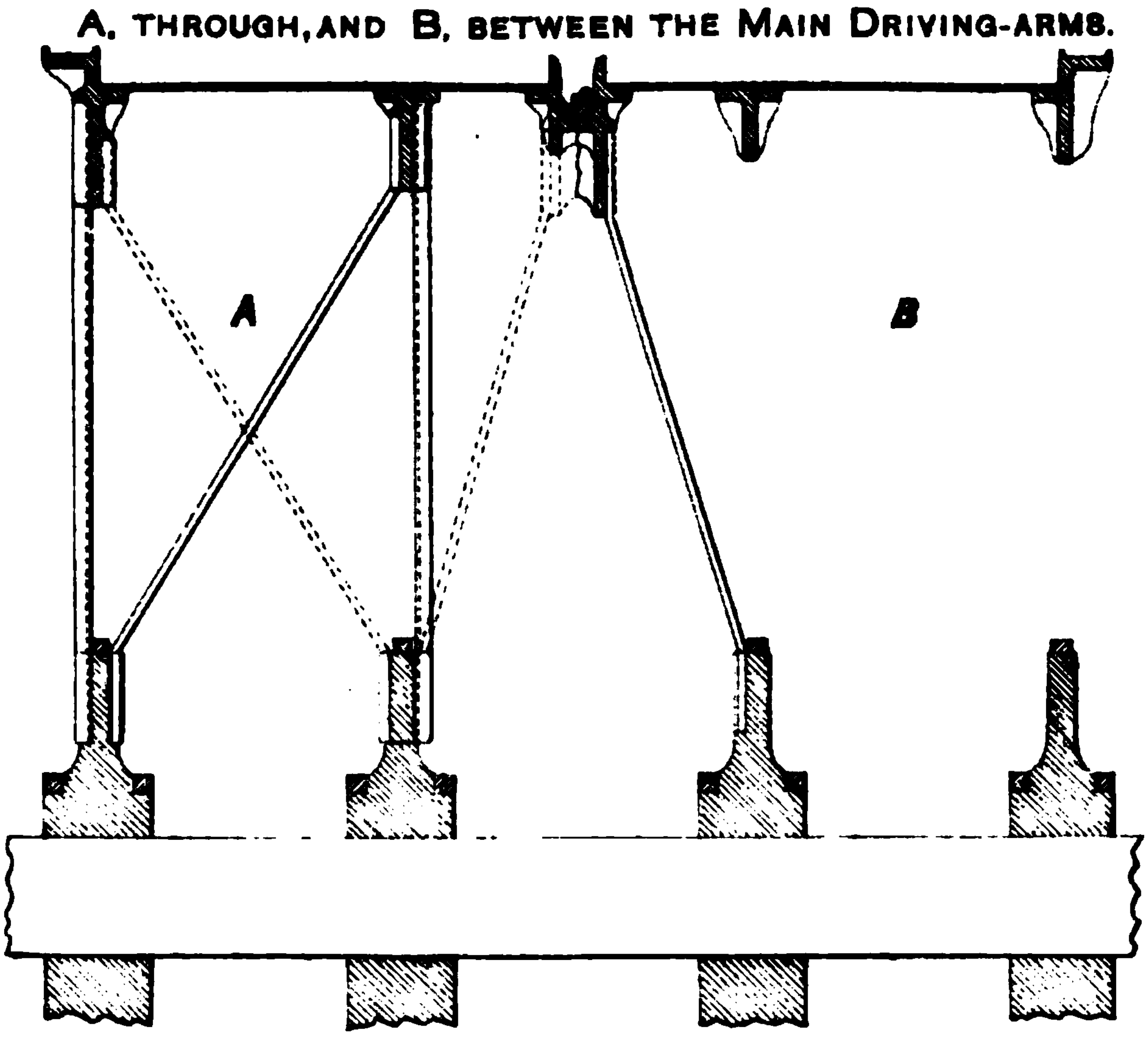
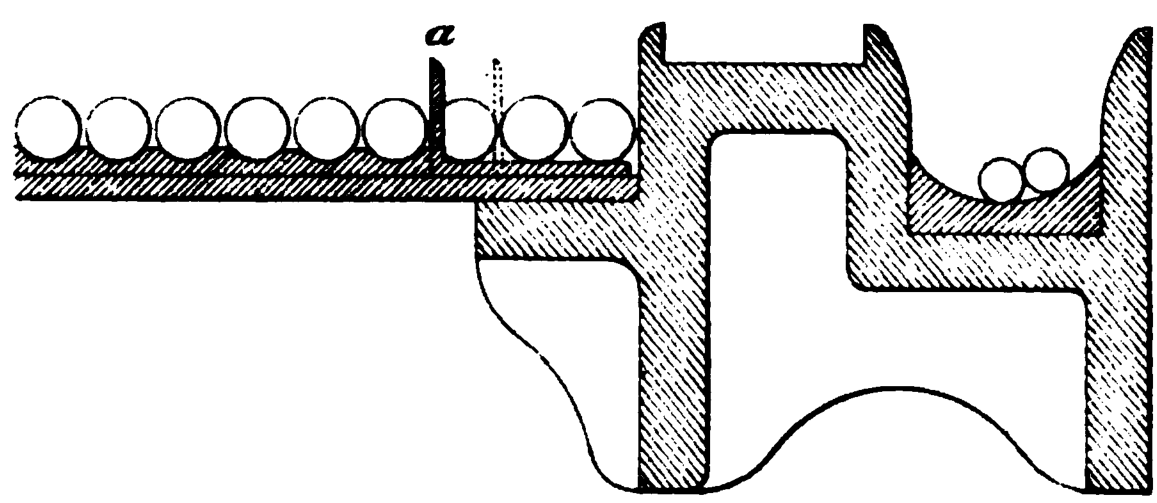


Fig. 5.—Cross-sections of Winding-drum: A, through, and B, between the Main Driving-arms.



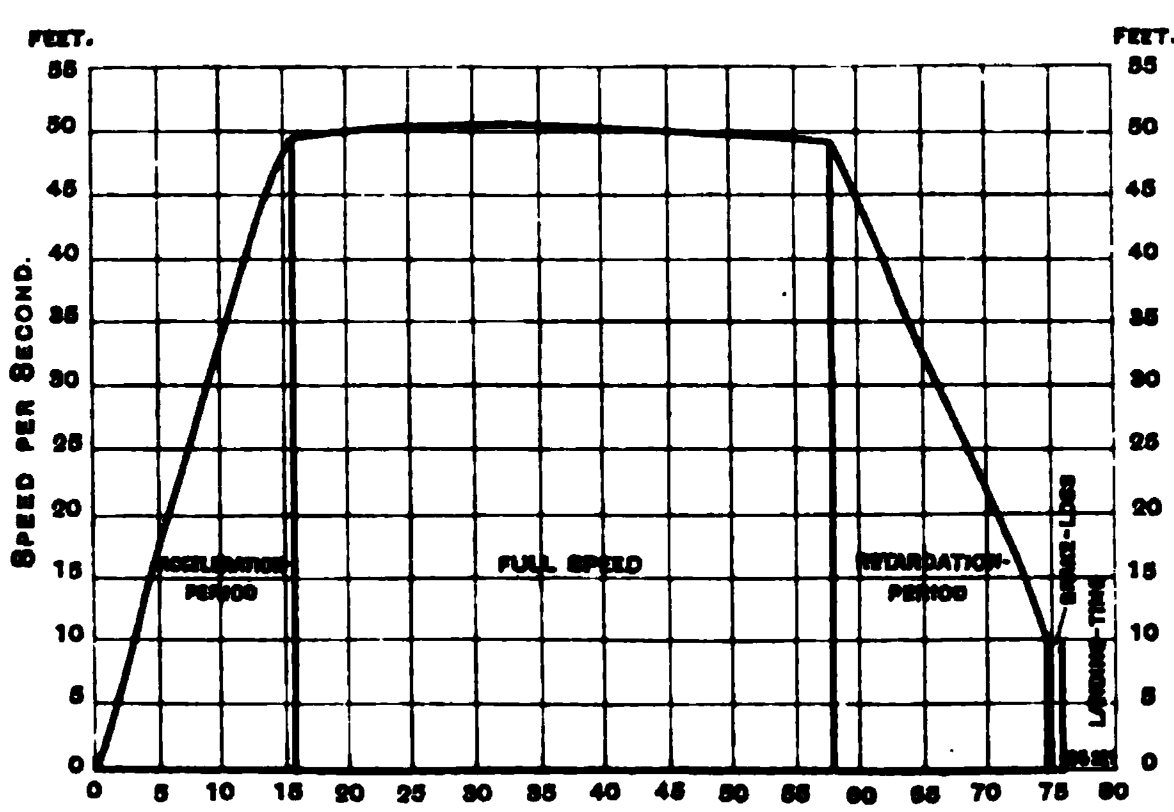
Scale, 6 Feet to 1 Inch.

Fig. 6.—Cross-section of Groove for Balance-rope.



Scale, 1 Foot to 1 Inch.

Fig. 9.



To illustrate Mr. W. G. Peasegood's Paper on "A Gob-fire in the Ten-feet Seam" etc.

Fig. 1.—Plan of Workings in Ten-feet Seam.

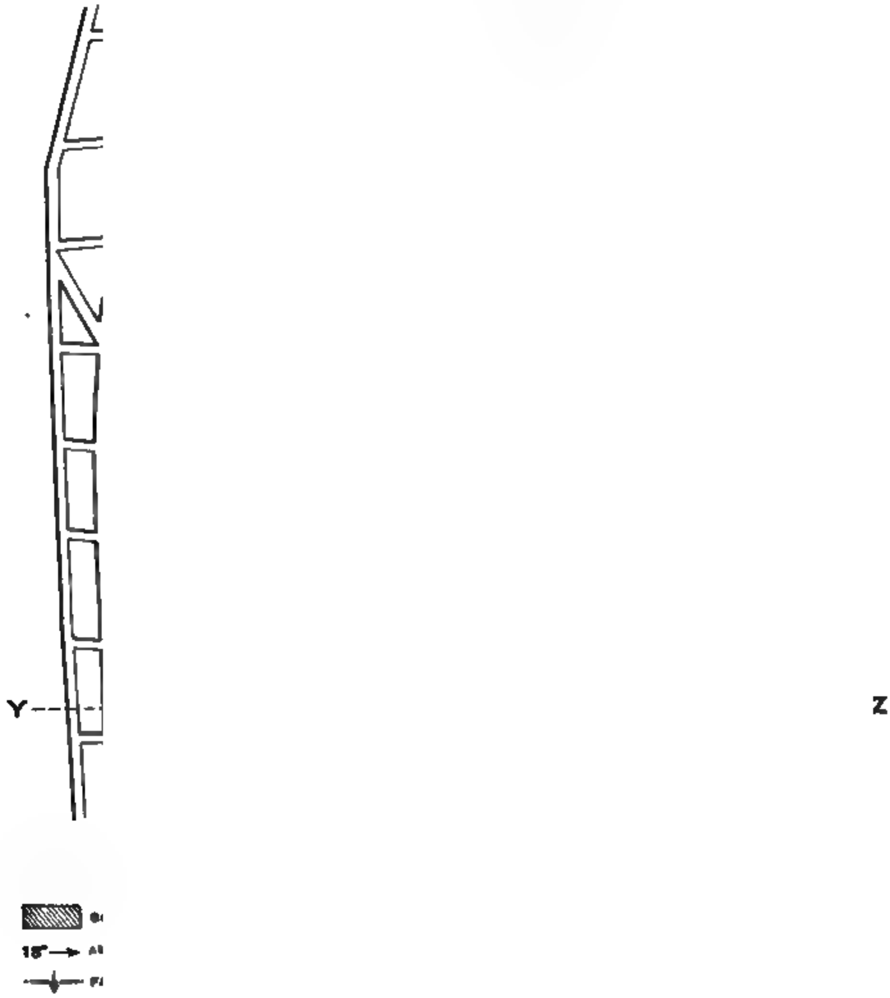
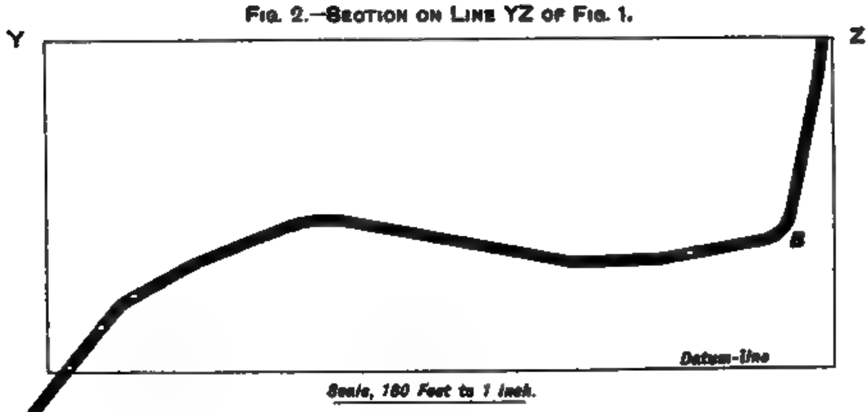
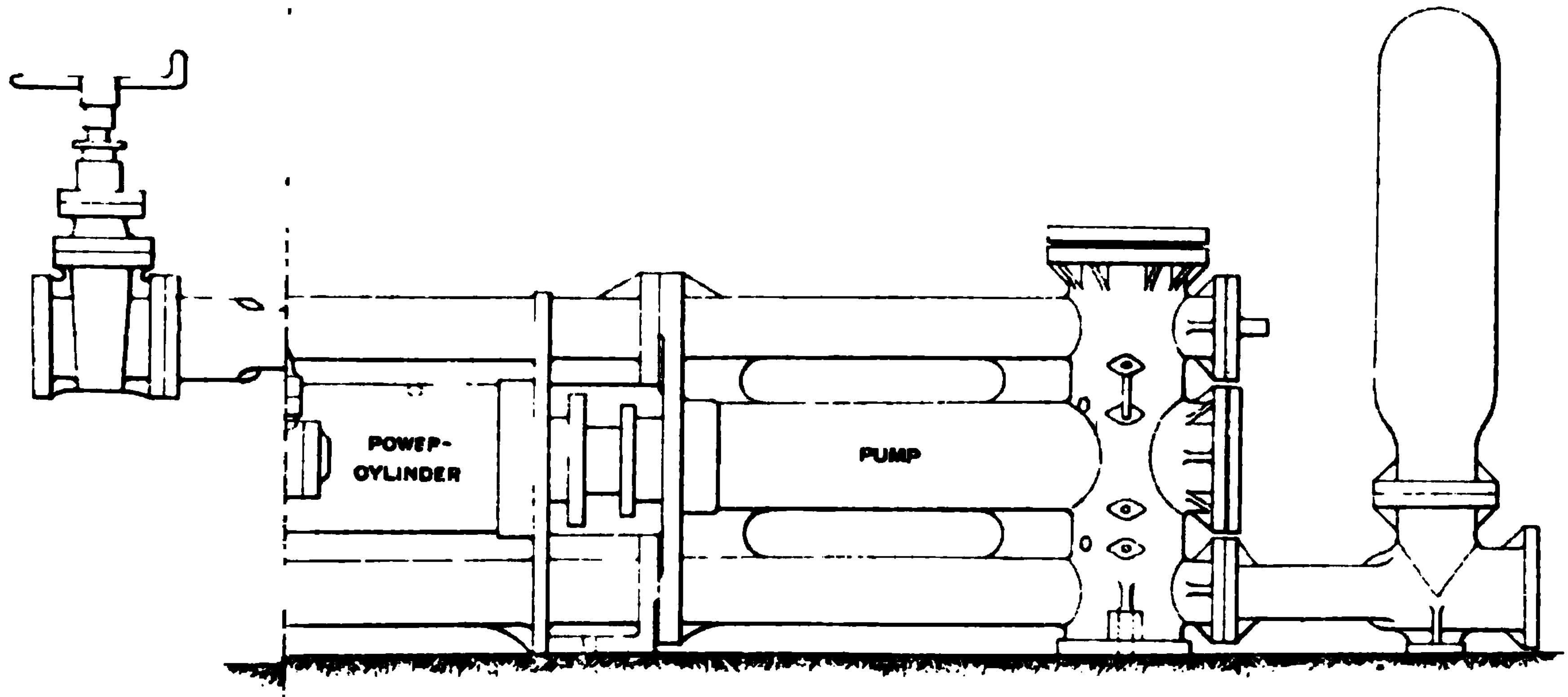


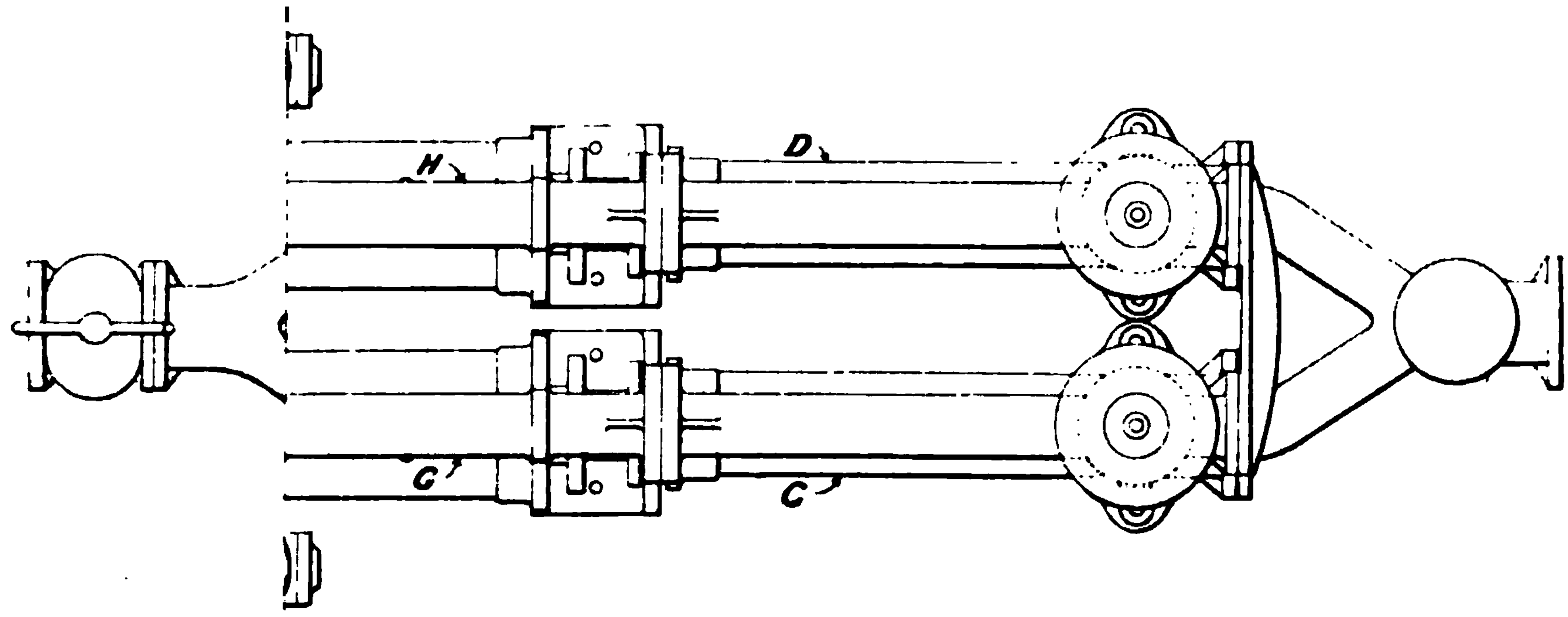
Fig. 2.—Section on Line YZ of Fig. 1.

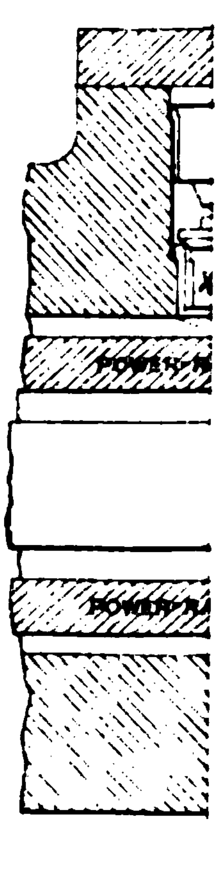


Scale, 160 Feet to 1 inch.

Andw. Reid & Compy. Ltd. Newcastle upon Tyne.







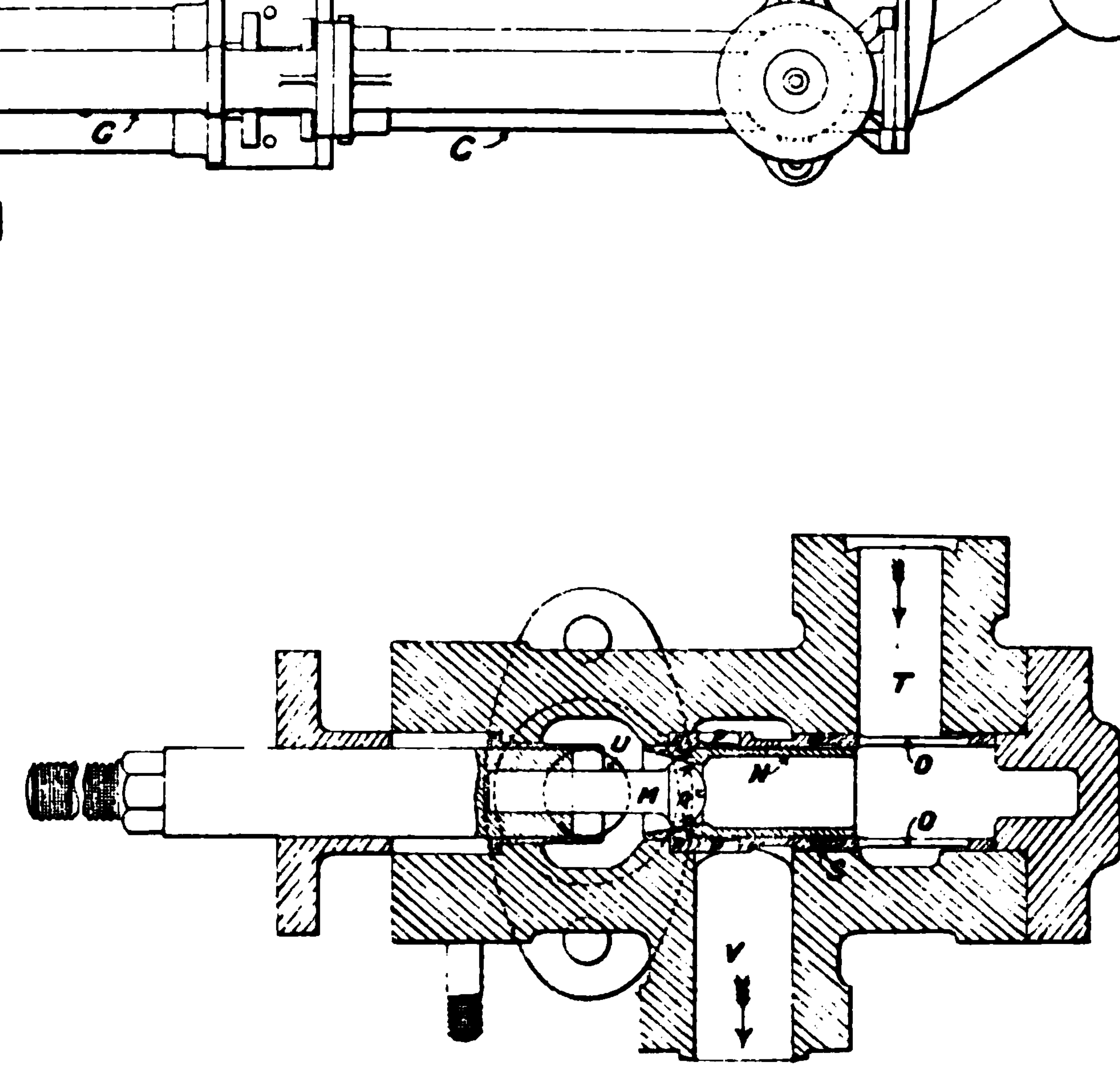
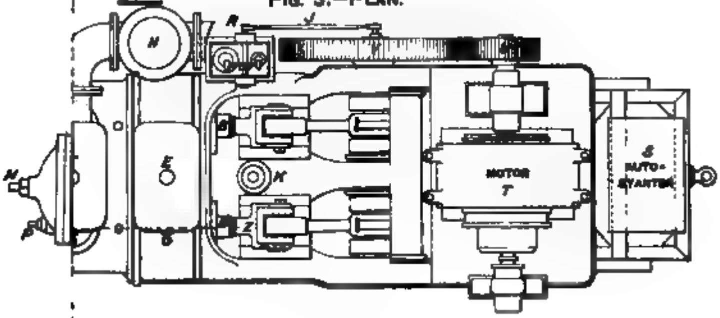


Fig. 3.-

Fig. 5.—Section of Motor-valve.

Scale, 1 Foot to 1 Inch

FIG. 3.—PLAN.



Scale, 4 Feet to 1 Inch.

The Institution of Mining Engineers
Transactions. 1905-1906 VOL. XXX., PLATE V.

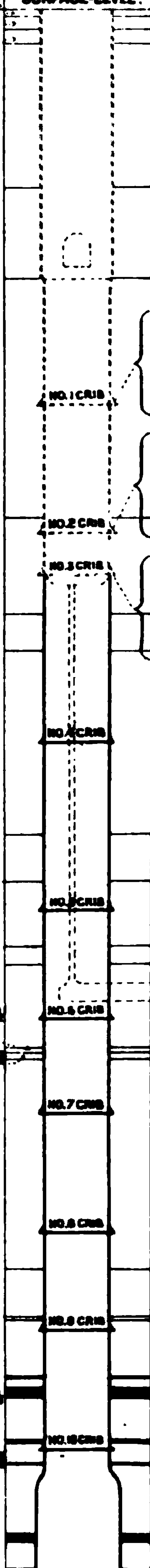
To illustrate Description of "Dawdon Colliery."

SECTIONS OF STRATA SUNK THROUGH AT DAWDON COLLIERY.

CASTLEREAGH SHAFT.

NO.	STRATA.	THICKNESS FT.	IN.
1	SOIL	1	0
2	CLAY	5	6
3	GRAVEL	4	6
4	STRONG MARL, WITH LIME-STONE-GIRDLES	50	10
5	LIMESTONE, WITH STRONG MARL-PARTINGS	32	7
6	MARL, WITH GULLETS	84	7
7	HARD GREY LIMESTONE	34	6
8	YELLOW LIME-STONE	18	2
9	HARD GREY LIMESTONE	65	7
10	GREY AND YELLOW LIME-STONE	17	6
11	YELLOW LIME-STONE	22	0
12	GREY LIMESTONE	5	6
13	GREY LIMESTONE IN PANELS	30	7½
14-15	MARL-SLATE	2	1
16	FISH-BED	1	0½
17	BLUE-GREY SAND	75	0
18	BROWN-GREY SAND	17	4
19	POST-GIRDLE	1	0
20	BLUE SHALE	21	0
21	COAL	0	3
22	GREY SHALE	2	5
23	COAL	4	4½
26	COAL	0	10
29	COAL	0	1½
38-40	COAL	3	5
43	COAL	0	7

SHAFT. SURFACE-LEVEL.



REMARKS.

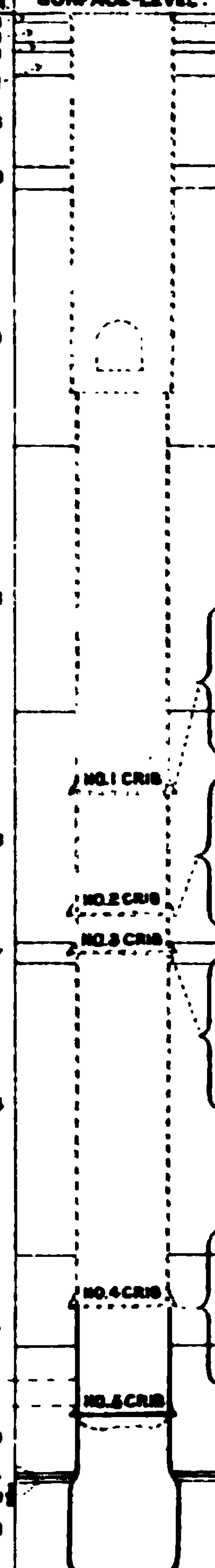
- FEEDER, 1,320 GALLONS PER MINUTE, 735 GALLONS LEFT AFTER PLUGGING-OFF
- FEEDER, 4,580 GALLONS PER MINUTE, 880 GALLONS LEFT AFTER PLUGGING-OFF
- FEEDER, 5,750 GALLONS PER MINUTE, 4,050 GALLONS LEFT AFTER PLUGGING-OFF

FEET

THERESA SHAFT.

NO.	STRATA.	THICKNESS FT.	IN.
1	SOIL	1	0
2	CLAY	5	0
3	GRAVEL	8	0
4	MARL, WITH LIME STONE	8	1
5	MARL	22	6
6	LIMESTONE	6	0
7	STRONG BEDDY MARL	66	0
8	STRONG MARL, IN BLOCKS	64	8
9	LIMESTONE, HONEYCOMBED	60	6
10	GREY MARL	4	7
11	GREY LIMESTONE	73	4
12	GREY LIMESTONE WITH LARGE GULLETS	28	4
13	HARD GREY LIMESTONE	31	0
14-15	MARL-SLATE	1	4
16	FISH-BED	0	10½
17	SAND, INTO	24	0

SHAFT. SURFACE-LEVEL.



REMARKS.

- FEEDER, 6,675 GALLONS PER MINUTE, 1,100 GALLONS LEFT AFTER PLUGGING-OFF
- FEEDER, 2,850 GALLONS PER MINUTE, 1,470 GALLONS LEFT AFTER PLUGGING-OFF
- FEEDER, 1,560 GALLONS PER MINUTE, 400 GALLONS LEFT AFTER PLUGGING-OFF
- FEEDER, 1,720 GALLONS PER MINUTE. 880 GALLONS LEFT AFTER PLUGGING-OFF

REFERENCES.

WORK DONE PREVIOUS TO ADOPTION OF FREEZING PROCESS IN 1906. ....

WORK DONE BY FREEZING PROCESS ————

Scale, 80 Feet to 1 Inch.

Andw Reid & Compy Ltd Newcastle upon Tyne

ubsided Strata.

A....

H

Fig. 3.—Diagram of Obliquities.

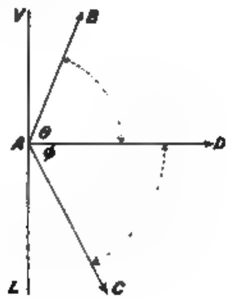


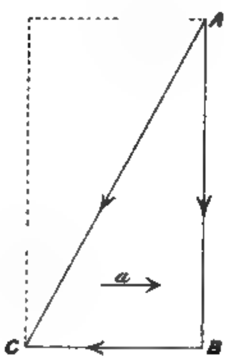
Fig. 10.—Reversed Fault.

C

A

a

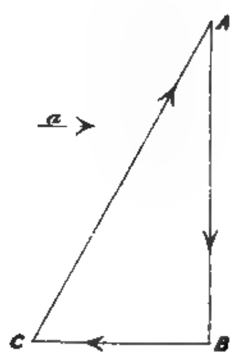
.—Parallelogram of Forces.



N

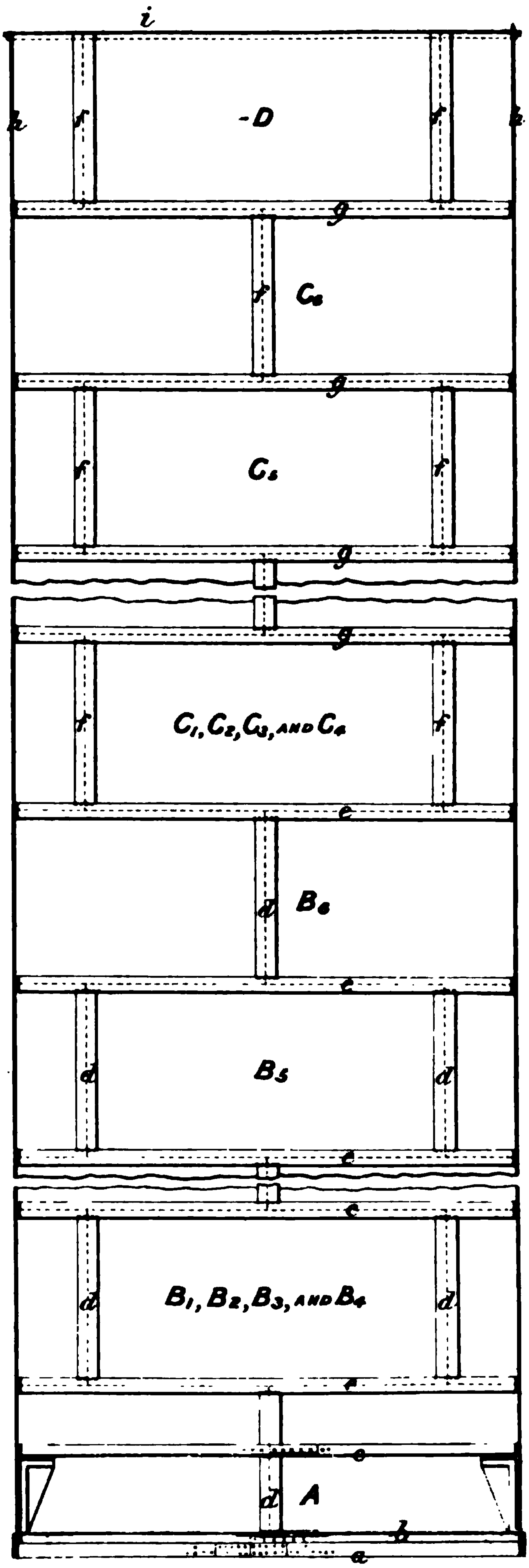
b

Fig 12.—Triangle of Forces in Equilibrium.



The

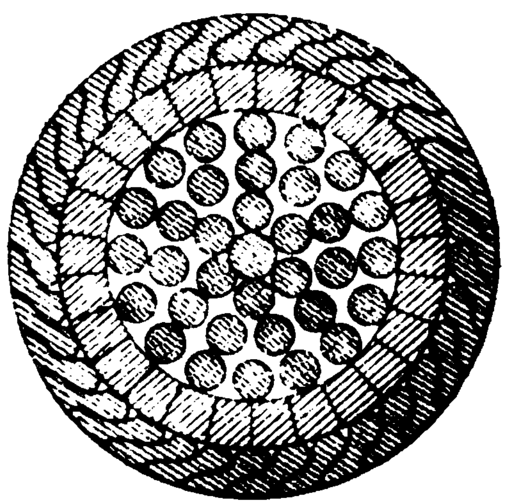
FIG. 5.—CROSS-SECTION OF CAISSON.



Scale, 8 Feet to 1 Inch.

To illustrate Mr. T. W. H. Mitchell's "Further Notes on Capels for Winding-ropes."

Fig. 1.



Full Size.

Fig. 2.

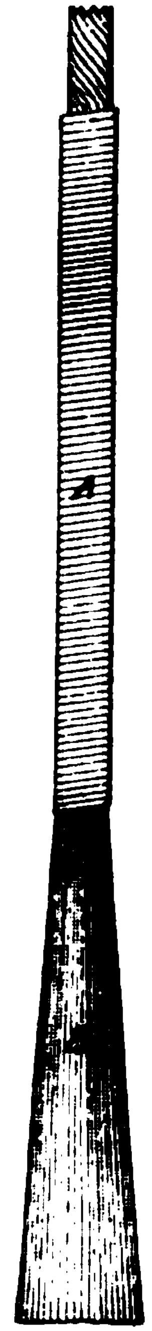


Fig. 3.

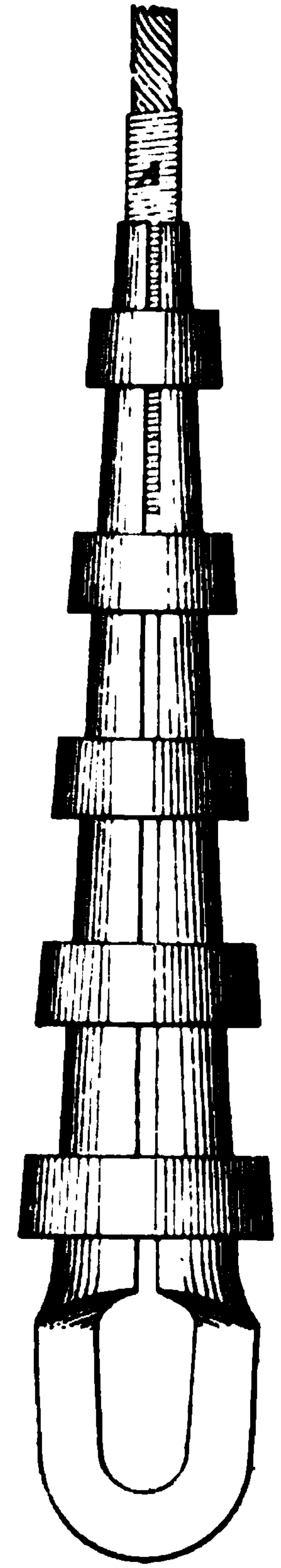


Fig. 4.

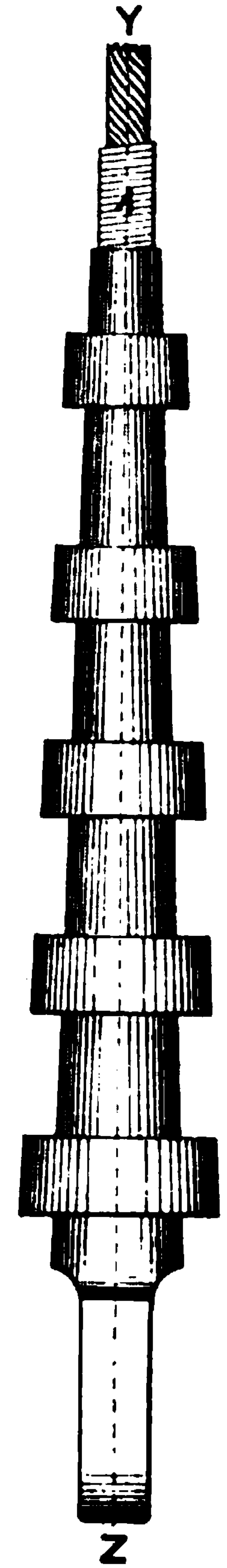


Fig. 5,

Fig. 6.

Fig. 7.

Fig. 8.

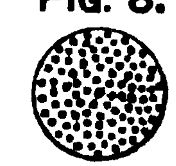
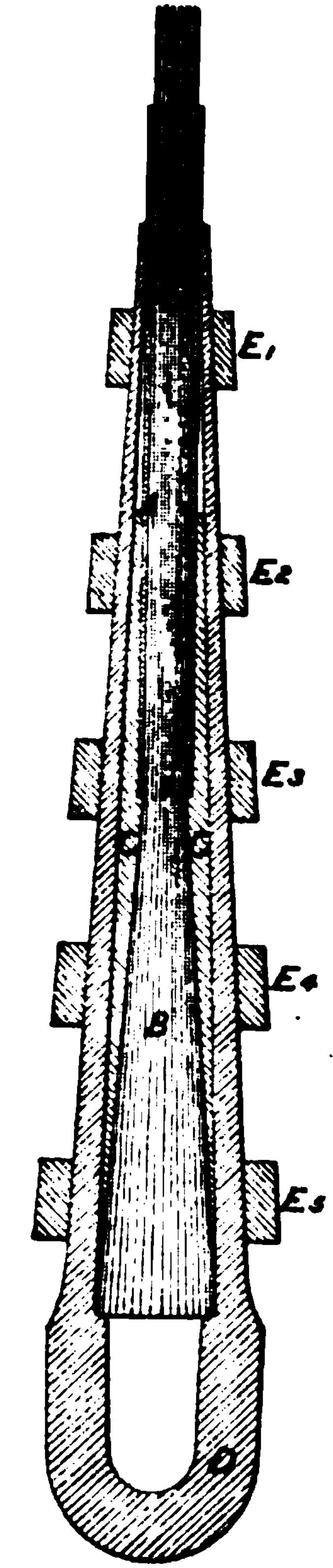


Fig. 9.—Section on Line YZ of Fig. 4.



Scale, 1 Foot to 1 Inch.

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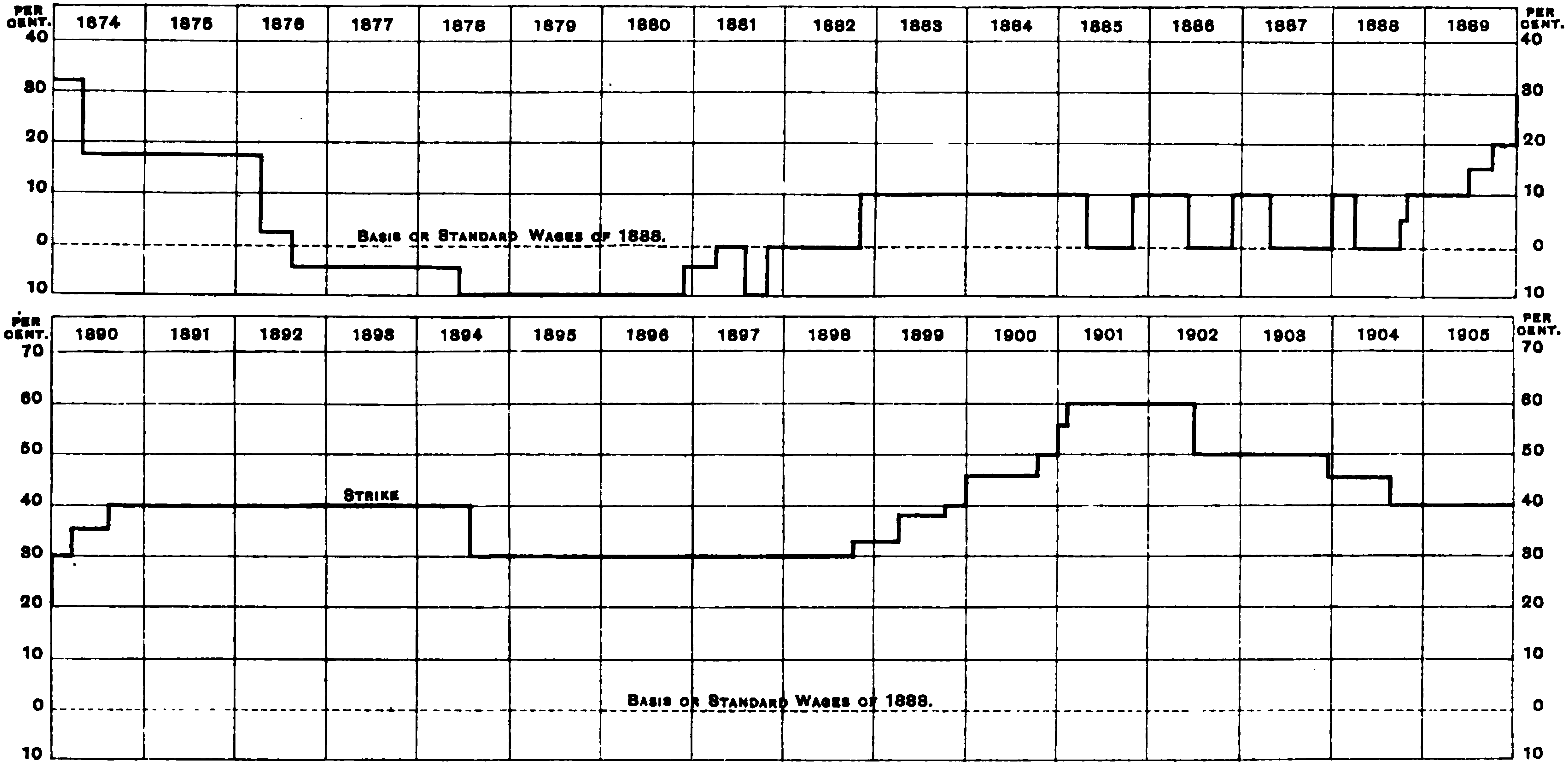
The Institution of Mining Engineers.
Transactions, 1905-1906.

To illustrate Mr. H. Bramall's "Presidential Address."

Vol. XXX., Plate IX.

DIAGRAM SHOWING THE VARIATIONS IN COLLIERS' WAGES IN RELATION TO THE BASIS OR STANDARD WAGES OF 1888.



The Manchester Geological and Mining Society.
Transactions, 1905-1906.

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Vol. XXIX., Plate V.

To illustrate Mr. B. H. Thwaite's Paper on "Can Explosions in Coal-mines, with their associated Toxic Fatalities, be prevented."

FIG. 1.—ELEVATION OF THE APPARATUS.

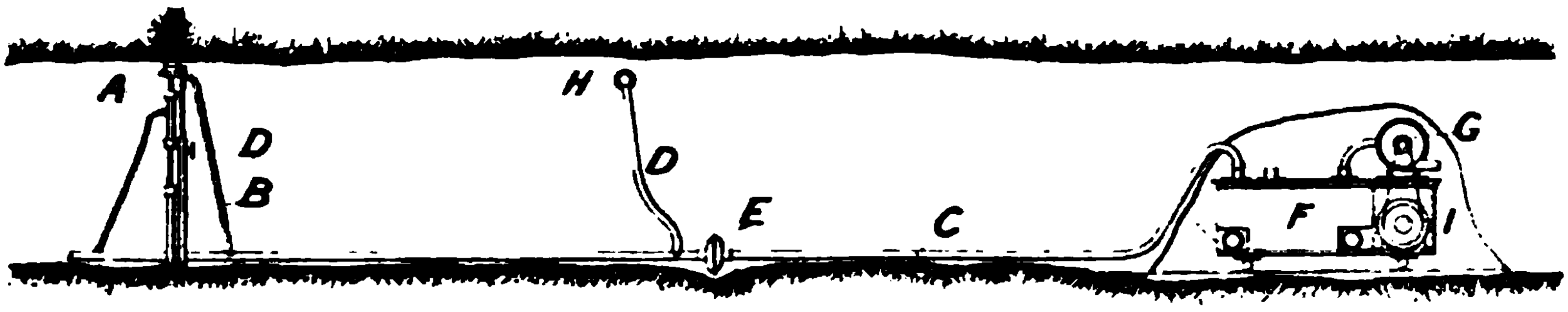

FIG. 2.—ELEVATION OF DUST-COLLECTOR, F.

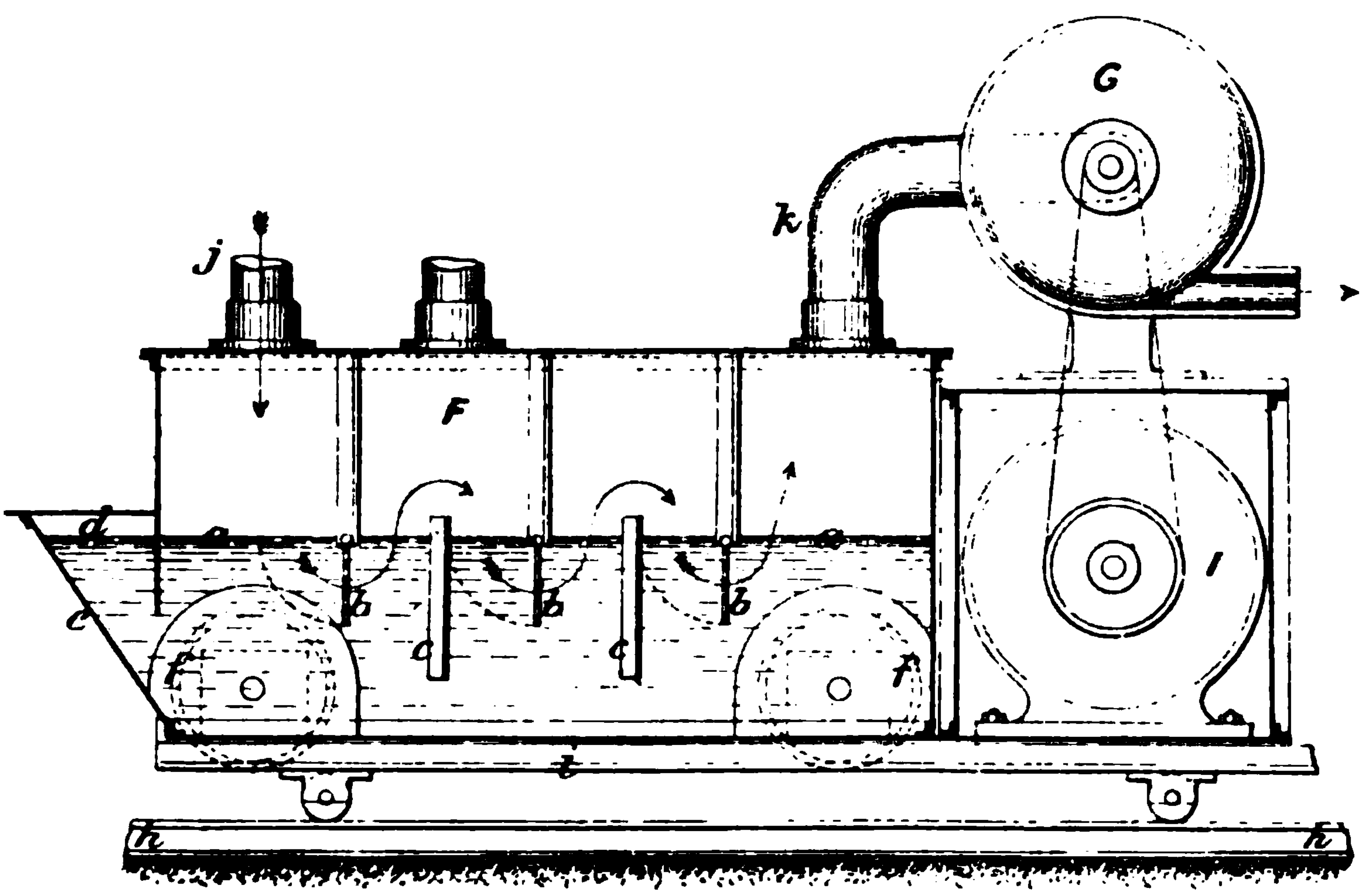

FIG. 3.—SECTION OF SUCKER-HOOD OR TERMINAL, A.

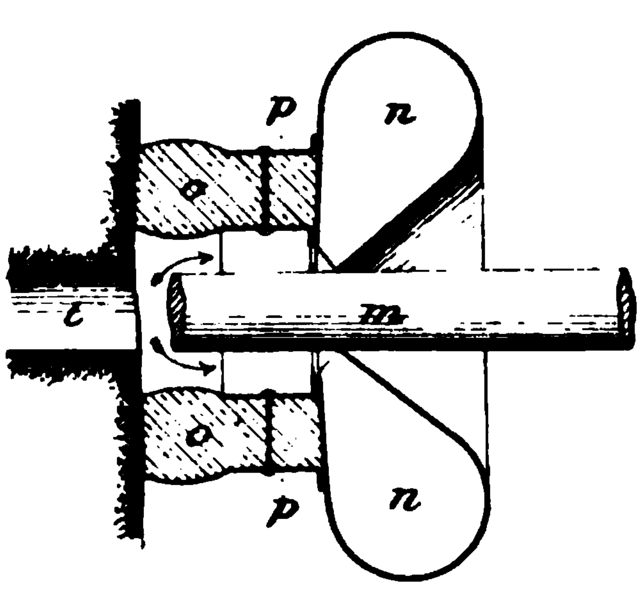

FIG. 4.—SECTION OF COUPLING, E, OF AIR-MAIN, C.

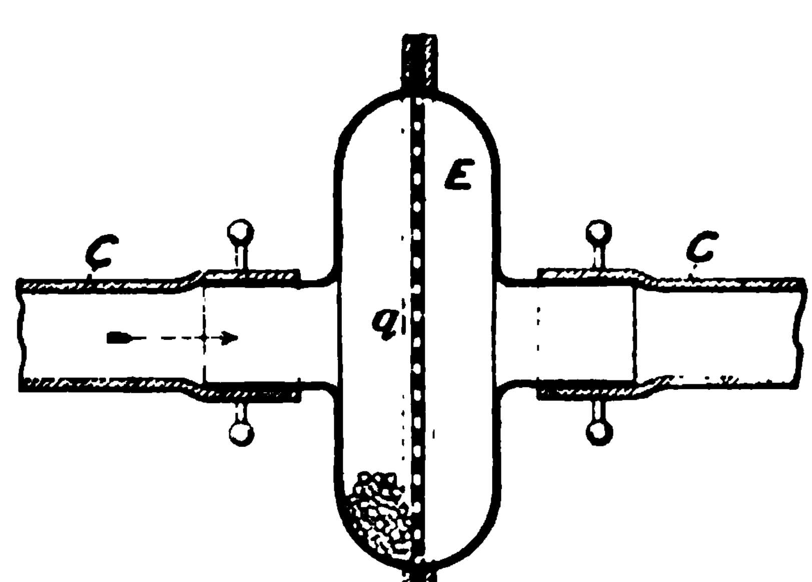

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FIG. 1.–

FIG. 4.—UNSAFE.

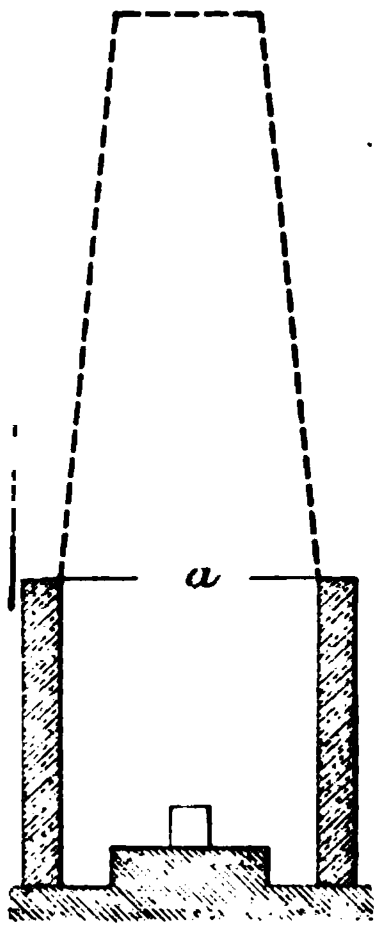
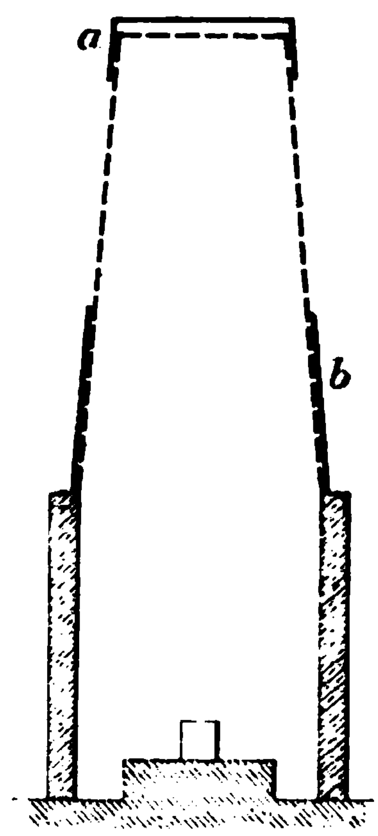


FIG. 5.—CONICAL FORM OF GAUZE.



CYLIND

FIG. 10.—EVAN-THOMAS NO. 7 SAFETY-LAMP

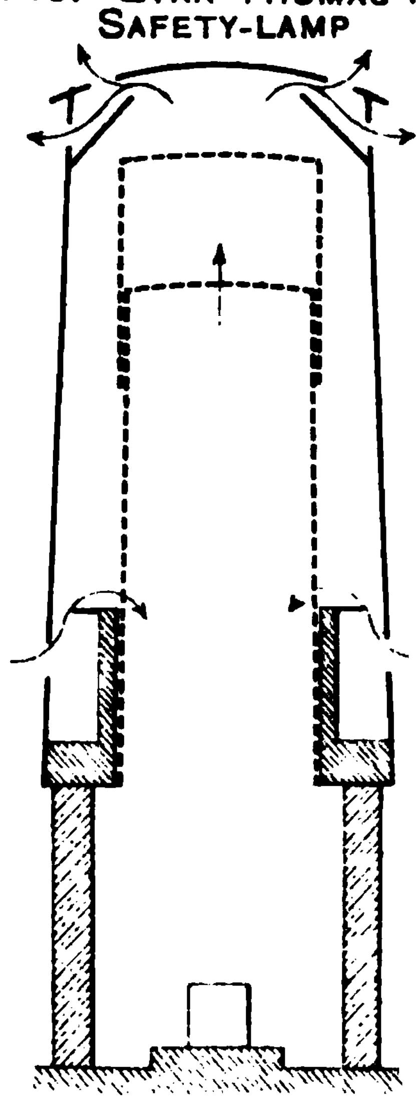
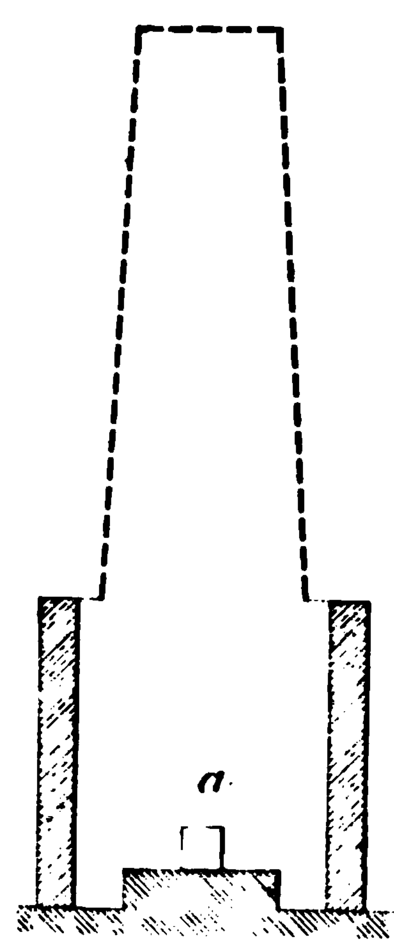


FIG. 11.



REFERENCES.

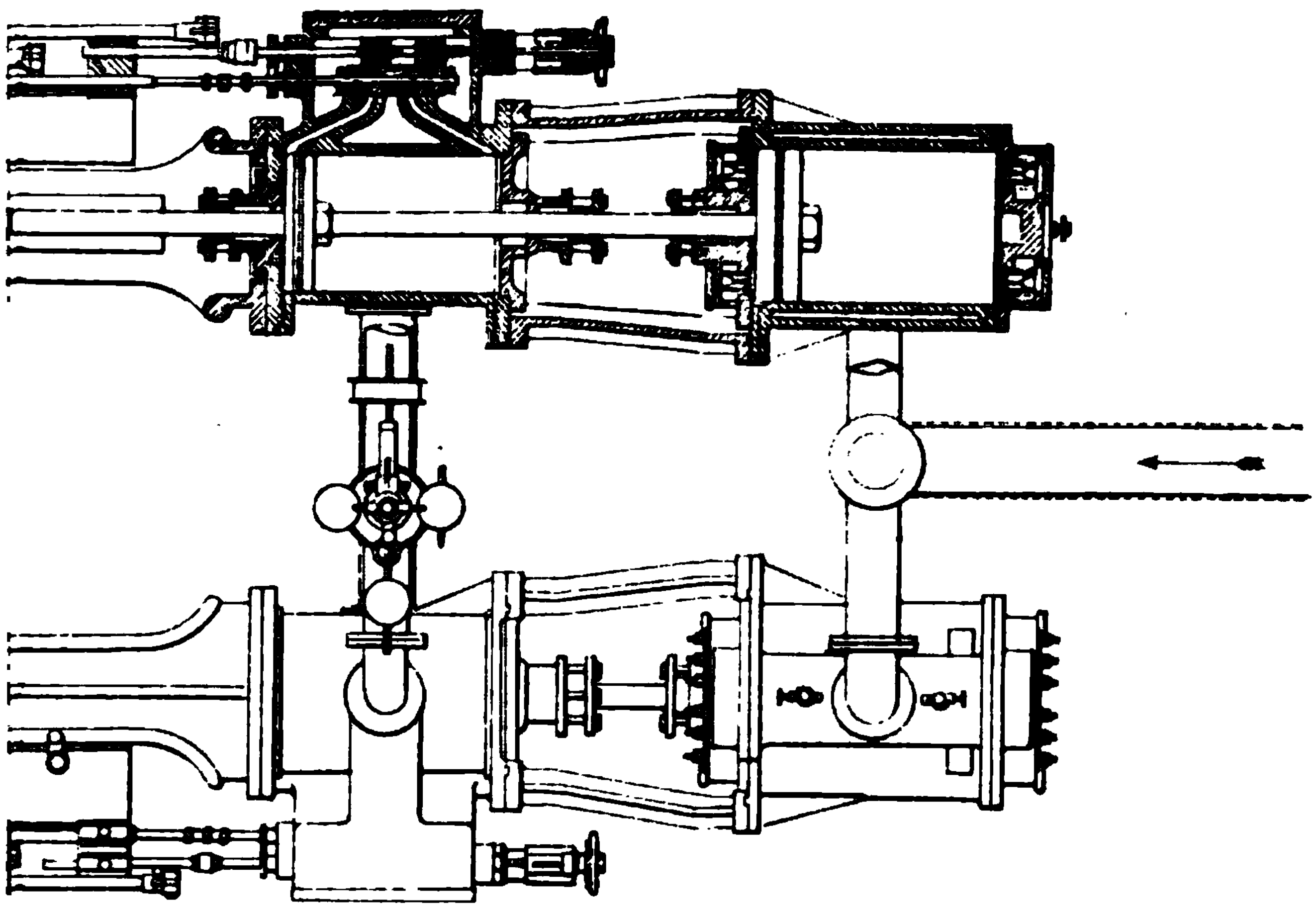
SHEET METAL ———

METAL .. .

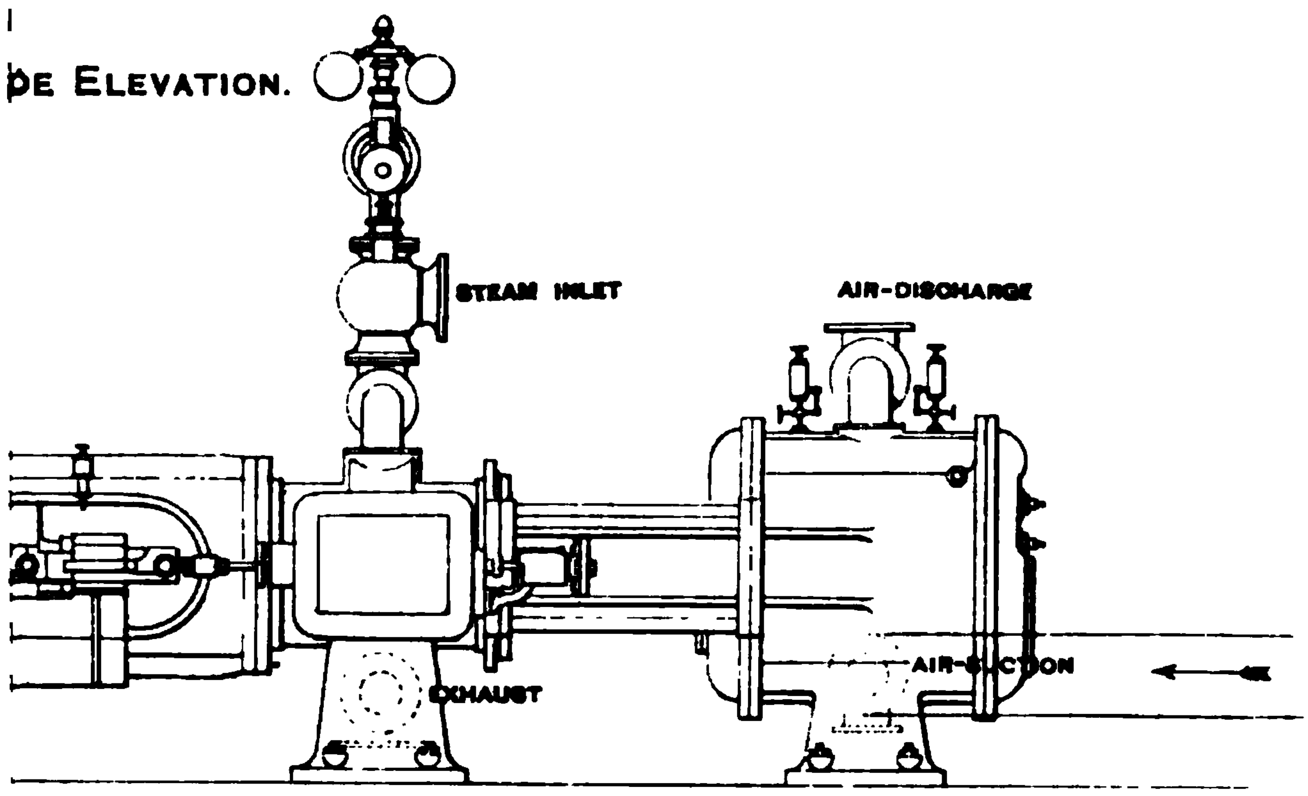
R-CURRENTS .... ——→

ON DUPLEX FORK-FRAME AIR-COMPRESSOR.

FIG. 3.—PLAN.

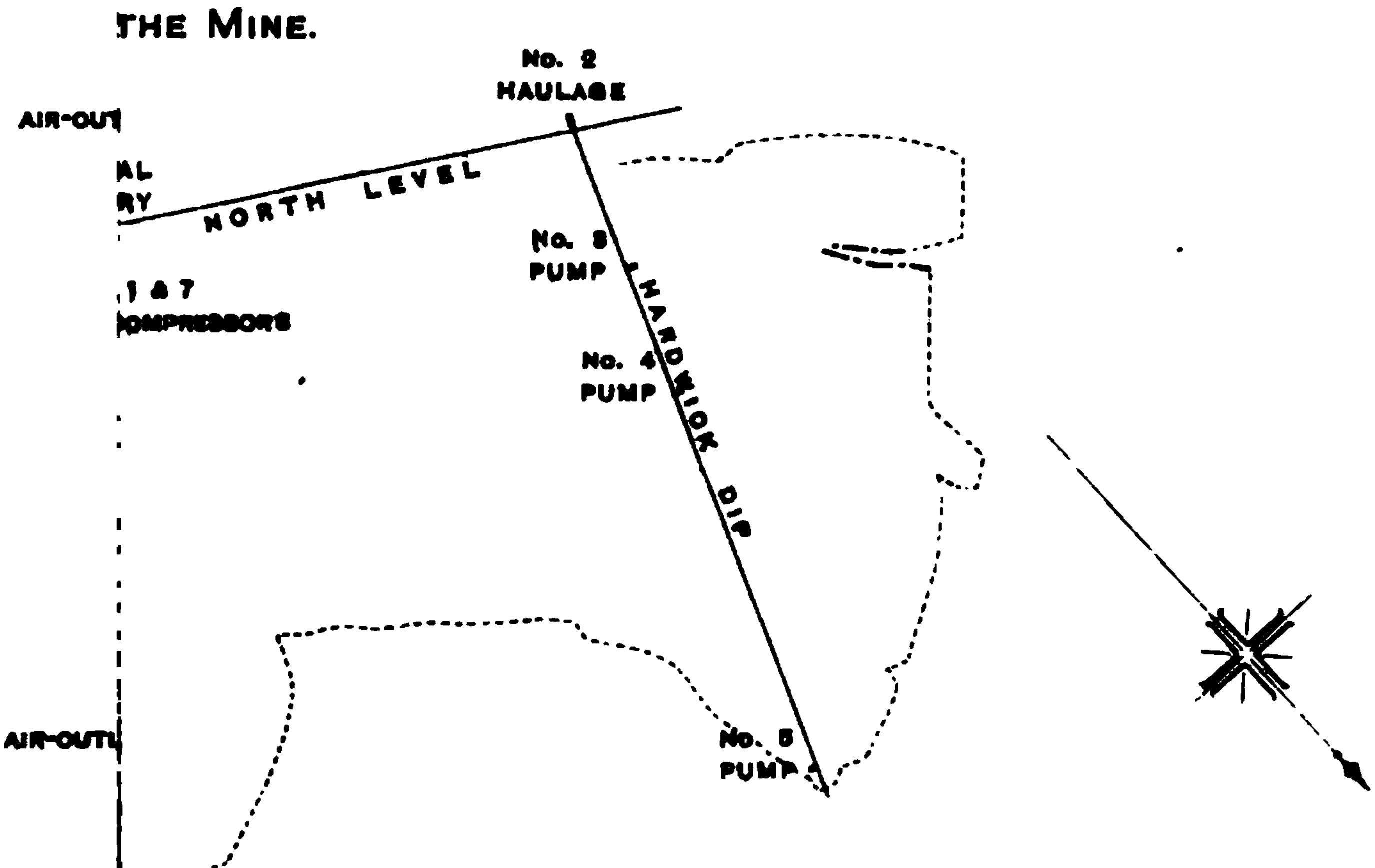


DE ELEVATION.



Scale, 4 Feet to 1 Inch.

AIR-COMPRESSORS ON THE SURFACE
THE MINE.



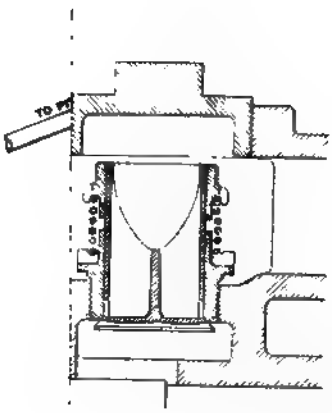
Scale, 2,640 Feet to 1 Inch.

YLINDERS.

Fig. 13.—Sections on Lines AB and CD of Fig. 12.

et to 1 inch.

Fig. 15.—Air Discharge-valve.



Scale, 4 inches to 1 inch.

Fig. 11.—Cross-sect

ing."

Vol. XXX. Plate XIV.

2.—Longitudinal-section of a Gateway.

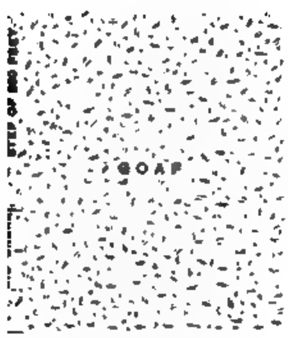
Scale, 24 Feet to 1 Inch.

Fig. 3.

GATEWAY

Scale, 24 Feet to 1 Inch.

Fig. 4.



Vol. XVII., Plate 17.

FIG.

FIG. 7.—SIDE VIEW

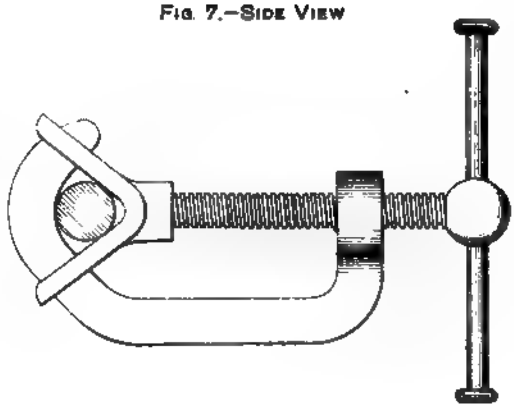


FIG. 8.—FRONT VIEW.

P

Scale, 6 Inches to 1 Inch.

G. 12.—END VIEW.

FIG. 13.—SIDE VIEW.

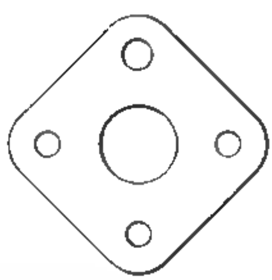


PLATE FOR ATTACHMENT OF BULL-CHAINS.

Scale, 1 Foot to 1 Inch.

Institution of Mining Engineers
Transactions 1905 1906.

To Illustrate Mr T. Beach's Paper on "Black Ends' their Cause, Cost and Cure."

Vol. XXX., Plate XVI.

Fig. 1.—Door without Recess.

Fig. 2.—Door with Recess.

Fig 3.
Front Elevation.

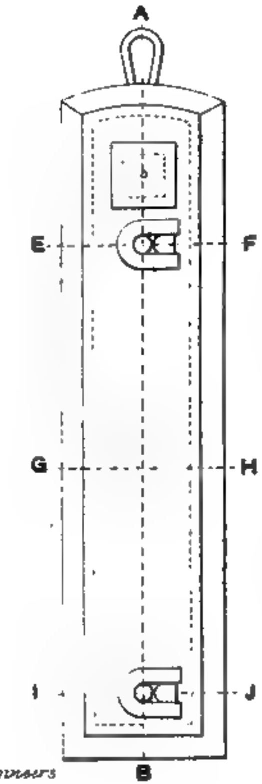


Fig 4.
Sectional Side Elevation on Line, AB, of Fig. 3.

Fig. 5.
Sectional Front Elevation on Line, CD, of Fig. 4.

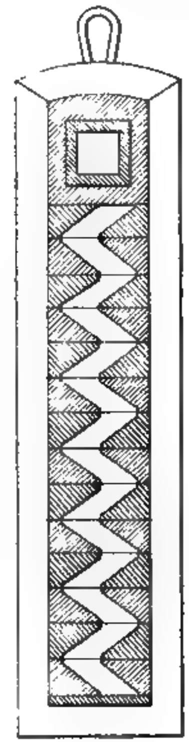


Fig. 6.—Sectional Plan on Line, EF, of Fig 3.

Fig. 7.—Sectional Plan on Line, GH, of Fig. 3.

Fig. 8.—Sectional Plan on Line, IJ, of Fig. 3.

Scale, 3 Feet to 1 Inch

Scale, 2 Feet to 1 Inch.

Scale, 2 Feet to 1 Inch

Midland Institute of Mining, Civil & Mechanical Engineers
Transactions 1905-1906.

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Vol. XVII, Plate VIII.

...on of Heading. Fig. 4.—Cross-section of Heading.

	Feet. Inches.
Bind	—
Coal	3 · 4
Hard fire-clay	1 · 6
Coal, soft	0 · 6
Dirt	0 · 5

	Feet. Inches.
Coal, two yards	—
Fire-clay	0 · 7
Coal, bare	2 5
Stone, ryder	0 · 4
Coal, ryder	—

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